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CONTROL SYSTEM FUNCTIONAL CRITERIA FOR MODERNIZED FORCED AIR DRY FACILITY

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This project was accomplished as part of the U.S. Army's Manufacturing Methods and Technology Program. The primary objective of this program is to develop, on a timely basis, manufacturing processes, techniques, and equipment for use in production of Army materiel. (cont)

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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

By addressing questions of coordination in a module composed of heating, drying, and pollution abatement processes, the functional criteria for the Forced Air Dry control system gives the designer a basic statement of the required control functions. A hierarchical structure has been developed for system and process analyses in order to determine the control hardware required for these control functions. Results, when available, from planned pilot plant operations are to be added to this hierarchical structure for development of a well-defined operating (cont)

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18. SUPPLEMENTARY NOTES (cont)

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20. ABSTRACT (cont)

strategy. This method of analysis and design development can be used for system engineering any pilot or full scale manufacturing system.

CONTENTS

FIGURES

I. INTRODUCTION

The control system functional criteria provides documentation of all operational influences required for the Forced Air Dry Process. The control of the facility has been developed through careful analyses and definition of equipment coordinations for startup, production and shutdown operations and transitions between these operations. This documentation is the result of the application of a structured design methodology developed at ARRADCOM for use in the definition of control systems for manufacturing processes. An understanding is developed by a four-part presentation: the operating goals, a process description, a summary of instrumentation and control functions required to operate the process according to the facility goals, and a discussion of discrepancies between project goals and the pilot plant processing scheme.

The goal of this Control System Functional Criteria is to address questions of coordination in a module composed of heating, drying, and pollution abatement processes. The intent is to use results from planned pilot operations to develop a well-defined operating strategy and its control requirements. This strategy can then be reconciled with the project goals and used for a multibay facility, with control management of production throughout and resource coordination.

The Control System Functional Criteria for Forced Air Dry is based on the following information sources available at the time of this writing:

1. Process configuration and operation review meeting, 29 Oct 80, Messrs. Bauman, Graff, and Lewis, ARRADCOM-LCWSL

2. Process configuration and operation review meeting, 3 Nov 80, Mr. Graff, ARRADCOM-LCWSL

3. Process configuration and operation plan overview, fonecon, 3 Nov 80, Messrs. Ziegler and Langford, Hercules Inc., RAAP

4. Process configuration and operation plan detail, fonecon, 7 Nov 80, Mr. Langford, Hercules Inc., RAAP

5. Project 57X4462, Modernized FAD for Multibased Propellants, letter, 19 Feb 80, from Hercules Inc., RAAP, to DRDAR-LCM-E

6. Project 57X4462, Modernized FAD for Multibased Propellants, letter, 14 Dec 79, from DRDAR-LCM-E to DRCPM-PBM-EP

7. Forced Air Dry, drawings, Hercules, Inc., RAAP:

491232	- 24066 - F35900	12/27/78
	- 24067 - F35900	12/8/78
	- 24073 - F35900	12/28/78
	- 24220 - F30300	3/30/79
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	- 24280 - F30200	3/10/79
	- 26097 - F35400	5/21/80
	- 26098 - F35700	5/21/80
	- 26189 - F35700	6/24/80
	- 26228 - F32700	7/2/80
	- 26229 - F32800	7/2/80

II. OPERATIONAL GOALS

The Forced Air Dry module is to be operated as a pilot project for the purpose of developing a thorough process and control understanding of issues related to the following:

1. Elimination of solvents and excess materials from green multibase propellant to a specified product quality requirement

2. Minimization of environmental pollution by removal of vapor stream contaminants to a specified air quality requirement

3. Demonstration of technical feasibility of solvent removal methods

Specific issues to be addressed in the operations of this module include the following:

1. Measurement and establishment of uniform heat distribution in the bay

2. Establishment of need for hot water supply and radiator panels in the bay

3. Determination of instrumentation, sensors, and actuators required to maintain the required drying bay temperature-time profile for various propellants

4. Determination of optimum sensor locations and control points for reliable and accurate bay temperature control

5. Establishment of flow of bay air which provides required temperature distribution and volume for uniform solvent removal from green propellant

6. Establishment of flow of air coordination for maintenance of small negative pressure in bay for safe operation (value of negative pressure to be determined)

7. Establishment of need for duct heating to prevent nitroglycerin condensation

8. Determination of temperatures, pressures, and flows and their correlations with organic waste removal effectiveness and efficiency

9. Determination of temperatures, pressures, and flows and their correlations with solvent removal effectiveness and efficiency

10. Identification of critical monitor points and alternative strategies for response to failure to meet operational requirements

11. Identification of operating strategy for effective and efficient drying operations, particularly with respect to multibay coordination

III. PROCESS DESCRIPTION

The Modernized Forced Air Dry system was analyzed to establish a common understanding of the project and a rationale for the existence of each elemental function in the process. This rationale constitutes a definitive statement of system functional criteria. Operation of the defined system, to meet specific performance requirements, is achieved by the application of control to the selected processing equipment. The complete system criteria statement includes the functional identification of processing activities and their control requirements to achieve specified system operation.

The rationale presented in this report focuses on specific system design development issues and specifies the purpose of the processing functions. Any constraints under which a function must be accomplished are identified, and the primary design decision which decomposes the processing function into subfunctions is traced. Necessary coordinations between the subfunctions are identified. Attention is called to obvious technological alternatives. Each subfunction in turn then becomes another design development issue to be further resolved. This "decomposition" is continued through each logical development issue until the subfunctions can be performed by actual processing equipment hardware.

This decomposition can be viewed as a hierarchy of design decision implications. Levels in this hierarchy have been distinguished by the span of implication and logical precedence. Issues at the upper levels have a broad scope and affect major portions of the system design. The decisions made at these levels determine a set of subordinate issues which then must be resolved. In contrast, issues in lower levels have a narrow scope and decisions at these levels have limited impact on the remainder of the system design. Each node represents an issue in the design development needing consideration and resolution before proceeding to lower nodes. Evidently, at some point in the decomposition, the resolution of an issue is expressible as a collection of process equipment hardware. The appearance of process equipment need not occur at the same position in each branch of the hierarchical tree. In fact, since different design issues vary in complexity, some branches may be long while others may be short before process equipment needs can be identified. The shape of the resulting hierarchy is a reflection of the engineering nature of the system, showing the most structure in those areas of most design complexity. By a regrouping of elemental operations, a more balanced hierarchy could be developed, but this would serve no useful purpose in this presentation.

The following outline identifies the logical design development decision hierarchy resolved for the Forced Air Dry process.

Forced Air Dry System

1. Hot Air Dry

1.1 Hot Air Supply

1.2 Dryer

1.2.1 Hot Air Distribution

1.2.2 Hot Water Supply

1.2.3 Drying Bay

2. Pollution Abatement

2.1 Nitroglycerin Removal

2.1.1 Caustic Solution Supply

2.1.2 Caustic Reaction

2.1.2.1 Multitray Column

2.1.2.2 Caustic Circulation

2.1.2.3 Duct Heater

2.1 Solvent Removal

2.2.1 Cold Water Supply

2.2.2 Solvent Absorption

2.2.2.1 Packed Column

2.2.2.2 Batch Accumulation

Successive stages of functional decomposition are identified by successive levels in the above outline. A stage-by-stage summary of stream interconnections of these functions is illustrated by the functional process flow decomposition diagram (figs. 1 and 2). This is done to assure continued compatibility across the system after each stage of issues is considered.

Having developed the process system criteria through the logical rationale, a review of the result according to the project guidelines of safety and economy shows the need for two additional functions, POLLUTION ABATEMENT BYPASS and SOLVENT REMOVAL BYPASS, and a long-range coordination, BAY INTERNAL PRESSURE, between two existing functions. These are summarized in the Additional Functions and Coordinations paragraph of this section.

SYSTEM DECOMPOSITION

FORCED AIR DRY

The objective of the Forced Air Dry System is to dry green (i.e., solvent-wet) multibase propellant subject to a specified maximum hydrocarbon (alcohol/acetone) contamination of the atmosphere. The prototype facility uses the existing forced air dry technology. This technique generates a solvent-laden air stream with nitroglycerin contamination. Allocation of objectives and constraints, using the specified technology, results in the following functional decomposition:

1. HOT AIR DRY: removes solvents from green propellant to meet product specifications.

2. POLLUTION ABATEMENT: removes hydrocarbons from the air stream to meet environmental specifications.

FIRST STAGE DECOMPOSITION

1. HOT AIR DRY

The objective of HOT AIR DRY is to remove solvents from green propellant to meet product specifications with a goal of a minimal nitroglycerin loss from the propellant. The existing forced air dry technology uses a variable drying rate. This variable drying rate is achieved by varying the temperature (the relative solvent humidity index) of a fixed air flow. The drying rate profile (temperature-time relationship) determines the amount of nitroglycerin loss from the propellant. Allocation of objectives and constraints, using the specified technology, results in the following functional decomposition:

1.1 HOT AIR SUPPLY: provides variable temperature air stream at a relatively constant air flow rate.

1.2 DRYER: provides enclosed area for contact drying of propellant. The following coordination is required between these subfunctions: the drying profile in the DRYER is established by adjusting the temperature of the HOT AIR SUPPLY.

2. POLLUTION ABATEMENT

The objective of POLLUTION ABATEMENT is to remove hydrocarbons from the air stream to meet environmental specifications, with a goal of saving the solvents by recovery and for reuse. The facility uses existing air/solvent separation technology. A problem with this technology is that it removes nitroglycerin at

the same time that it removes the solvents from the propellant. Allocation of objectives and constraints, using the specified technology, results in the following functional decomposition:

2.1 NITROGLYCERIN REMOVAL: eliminates nitroglycerin contamination from the air stream.

2.2 SOLVENT REMOVAL: separates solvents from the air stream.

The following coordination is required between these subfunctions: NITROGLYCERIN REMOVAL must eliminate sufficient nitroglycerin so that the solvents separated from the air stream are uncontaminated.

SECOND STAGE DECOMPOSITION

1.1 HOT AIR SUPPLY

The objective of HOT AIR SUPPLY is to provide variable temperature air at a relatively constant air flow rate, with a goal of minimal energy use for air heating. The technology used is a dual air flow configuration, with one air stream ambient and the other air stream heated by a constant steam flow. Varying the combination of the two streams provides the variable temperature. Allocation of objectives and constraints, using the specified technology, results in the following implementation (fig. 3):

1.1.1 HX-1: provides for the transfer of heat from steam to an air stream.

1.1.2 P-1: provides a relatively constant air flow rate

1.1.3 FV-5: blocks the steam flow to HX-1.

1.1.4 FV-6: varies the combination ratio of heated and ambient air streams.

An alternate technology would be to use a single air stream with throttled steam heat to provide the variable temperature.

1.2 DRYER

The objective of DRYER is to provide an enclosed area for contact drying of the propellant for uniform drying of the batch. The technology used is the continuous circulation of fresh hot air around the propellant. A problem of this technology is that environmental exposure of DRYER can cause uneven heat loss and consequent nonuniformity of drying. Allocation of objectives and constraints, using the specified technology, results in the following functional decomposition:

1.2.1 HOT AIR DISTRIBUTION: directs hot air flow for uniform drying.

1.2.2 HOT WATER SUPPLY: provides hot water heat for balancing heat loss in DRYING BAY.

1.2.3 DRYING BAY: provides an enclosed area with balanced heat loss for physical contact between propellant and hot air.

2.1 NITROGLYCERIN REMOVAL

The objective of NITROGLYCERIN REMOVAL is to eliminate nitroglycerin contamination from the air stream, with a goal of minimal simultaneous removal of solvents. The technology used destroys nitroglycerin by caustic reaction. Allocation of objectives and constraints, using the specified technology, results in the following functional decomposition:

2.1.1 CAUSTIC SOLUTION SUPPLY: provides caustic water to CAUSTIC REACTION.

2.1.2 CAUSTIC REACTION: decomposes nitroglycerin in the air stream without removing solvents.

The following coordination is required between these subfunctions:

a. composition of caustic water for reaction must be fixed by CAUSTIC SOLUTION SUPPLY.

b. CAUSTIC SOLUTION SUPPLY must provide the volume of caustic water required by operation of CAUSTIC REACTION.

2.2 SOLVENT REMOVAL

The objective of SOLVENT REMOVAL is to separate solvents from the air stream, with a goal of obtaining them in a form compatible with existing recovery methods. The technology used is cold water condensation and absorption. Le Chatelier's principle indicates that absorption is enhanced by lower water temperatures. Allocation of objectives and constraints, using the specified technology, results in the following functional decomposition:

2.2.1 COLD WATER SUPPLY: provides cold water to SOLVENT ABSORPTION.

2.2.2 SOLVENT ABSORPTION: condenses and absorbs solvents from the air stream into a cold water stream compatible with existing recovery methods.

The following coordination is required between these subfunctions:

a. Temperature of cold water must be fixed by COLD WATER SUPPLY.

b. COLD WATER SUPPLY must provide the volume of cold water required by SOLVENT ABSORPTION.

THIRD STAGE DECOMPOSITION

1.2.1 HOT AIR DISTRIBUTION

The objective of HOT AIR DISTRIBUTION is to direct the hot air flow for uniform drying. The technology used is multiple air ports distributed in the DRYING BAY. Allocation of objectives and constraints, using the specified technology, results in the following implementation (fig. 3):

1.2.1.1 LVR (louver): directs air flow from multiple ports.

1.2.2 HOT WATER SUPPLY

The objective of HOT WATER SUPPLY is to provide hot water to the DRYING BAY with a goal of minimal energy consumption for heating. The technology used is to circulate a hot water/glycol mixture to radiators in the DRYING BAY. Allocation of objectives and constraints, using the specified technology, results in the following implementation (fig. 3):

1.2.2.1 TK-1 (jacketed tank): provides for heat transfer from steam to the water/glycol mixture.

1.2.2.2 P-2: provides circulation drive for hot water/glycol mixture.

1.2.2.3 FV-2: throttles steam to tank jacket.

The following items are needed for startup, shutdown, or other nonproduction modes of operation:

1.2.2.4 FV-1: blocks water/glycol fill to TK-1.

1.2.3 DRYING BAY

The objective of DRYING BAY is to provide an enclosed area with balanced heat loss for physical contact between propellant and hot air, with a goal of minimal heat loss, minimal air stream loss to atmosphere, and minimal propellant handling hazard. The technology used is existing drying bay design and dual radiator circuits to balance heat loss across the bay. Allocation of objectives and constraints, using the specified technology, results in the following implementation (fig. 3):

1.2.3.1 BAY-1: provides an area for safe propellant handling and for physical contact between propellant and hot air.

1.2.3.2 FV-3 (bay doors): provides for propellant loading/unloading access and closes BAY-1 for minimal heat and air stream loss.

1.2.3.3 FV-4: varies hot water split between dual radiator circuits.

1.2.3.4 HP-1/HP-2 (heating panels): radiates heat from hot water to bay interior.

2.1.1 CAUSTIC SOLUTION SUPPLY

The objective of CAUSTIC SOLUTION SUPPLY is to provide caustic water of fixed composition and volume to CAUSTIC REACTION. The technology used is to mix caustic soda and water in a specified batch size. Allocation of objectives and constraints, using the specified technology, results in the following implementation (fig. 3):

2.1.1.1 TK-7: provides holdup for batch preparation.

2.1.1.2 AG-1: provides for the mixing of caustic soda and water.

2.1.1.3 P-11: provides the drive for transfer of caustic water.

The following items are needed for startup, shutdown, or other nonproduction modes of operation:

2.1.1.4 FV-16: blocks the water fill to TK-7.

2.1.1.5 FV-17: blocks the caustic water drain of TK-7.

2.1.2 CAUSTIC REACTION

The objective of CAUSTIC REACTION is to decompose nitroglycerin in the air stream, with a goal of minimal solvent removal and minimal caustic water and energy use. The technology used to bring the air stream into contact with caustic water is a multitray column with a caustic water volume circulated in multiple passes through the column. The operating temperature is determined by hot air temperature and caustic water temperature. Because water is evaporated from caustic water into the hot air stream, the return flow of caustic water from the column is less than the flow of caustic water to the column. Water makeup of the caustic water volume in CAUSTIC CIRCULATION is used to compensate for this. Allocation of objectives and constraints, using the specified technology, results in the following functional decomposition:

2.1.2.1 MULTITRAY COLUMN: establishes a physical contact between air stream and caustic water.

2.1.2.2 CAUSTIC CIRCULATION: provides for a continuous circulation of a caustic water batch of minimum strength through MULTITRAY COLUMN.

2.1.2.3 DUCT HEATER: maintains nitroglycerin safely in the gas phase between DRYING BAY and MULTITRAY COLUMN.

The caustic water batch degrades through continued use. An alternate technology would be to continuously refresh the caustic water in CAUSTIC CIRCULATE and purge the degraded material. Water makeup may or may not be needed in that technology. The tradeoff involved is between the selected technology, which is the size of the initial caustic water batch required to maintain adequate strength against degradation, and alternate technology, which is to use a smaller initial batch with an additional volume of caustic water refresh as needed. Winter operations may cause operating temperatures to be so low as to hinder nitroglycerin destruction and simultaneously to remove solvent. There is an economic tradeoff between the cost of adding a heating requirement to CAUSTIC CIRCULATION and the cost of solvent loss by either premature removal or nitroglycerin contamination.

2.2.1 COLD WATER SUPPLY

The objective of COLD WATER SUPPLY is to provide sufficient cold water to SOLVENT ABSORPTION, with a goal of minimal energy use. The technology used is inline cooling, if required, of an available water supply. Allocation of objectives and constraints, using the specified technology, results in the following implementation (fig. 3):

2.2.1.1 TK-4: provides a supply of water to supplement plant water supply rate.

2.2.1.2 CH-1: provides inline chilling of water.

2.2.1.3 P-7: provides a drive for water flow.

2.2.1.4 FV-8: provides a bypass of CH-1 when water is cold enough.

The following items are needed for startup, shutdown, or other nonproduction modes of operation:

2.2.1.5 FV-7: blocks the water fill to TK-4.

2.2.1.6 FV-9: blocks the drain from TK-4.

2.2.2 SOLVENT ABSORPTION

The objective of SOLVENT ABSORPTION is to condense and absorb solvents from the air stream into a cold water stream compatible with existing recovery methods. The technology used brings the solvent-laden air stream into contact with cold water in a packed column. The packed column operates at a low temperature with continuous cold water feed making a single pass through the column. Allocation of objectives and constraints, using the specified technology, results in the following functional decomposition (fig. 3):

2.2.2.1 PACKED COLUMN: establishes a physical contact between air stream and cold water.

2.2.2.2 BATCH ACCUMULATION: averages composition fluctuations in the solvent solution from PACKED COLUMN for compatibility with existing recovery methods.

FOURTH STAGE DECOMPOSITION

2.1.2.1 MULTITRAY COLUMN

The objective of MULTITRAY COLUMN is to establish physical contact between the air stream and caustic water. The technology used is a sieve tray column with air exhauster to draw the air stream through the caustic water on the trays. A problem with this technology is that reused caustic water, degraded by reaction, carries solids which may plug sieve trays. Allocation of objectives and constraints, using the specified technology, results in the following implementation (fig. 3):

2.1.2.1.1 CS-1: provides trays of caustic water through which the air stream can bubble.

2.1.2.1.2 P-3 (exhauster): provides a drive for transfer of the air stream through sieve trays in CS-1.

2.1.2.1.3 FV-18: throttles the caustic water flow to CS-1.

2.1.2.1.4 FV-19: throttles the caustic water flow from CS-1 to prevent flooding of bottoms.

2.1.2.2 CAUSTIC CIRCULATION

The objective of CAUSTIC CIRCULATION is to continuously circulate a caustic water batch of minimum strength through MULTITRAY COLUMN. The technology used is dual holdup and dual circulation sources to guard against single circuit failure and to provide a fresh caustic water batch for circulation, if necessary. Since water is lost from the caustic water batch in CS-1, additional water is added here to maintain the batch size. The circulation temperature is determined by the caustic water return temperature and makeup water temperature. Allocation of objectives and constraints, using the specified technology, results in the following implementation (fig. 3):

2.1.2.2.1 TK-2/TK-3: provides a primary/alternate caustic water holdup.

2.1.2.2.2 P-5/P-6: provides a drive for transfer of caustic water from TK-2/TK-3 to CS-1.

2.1.2.2.3 FV-28: selects a primary or alternate circuit return of caustic water from CS-1.

2.1.2.2.4 FV-24/FV-25: blocks the caustic water circulation flow from TK-2/TK-3.

2.1.2.2.5 FV-22/FV-23: throttles the water makeup to TK-2/TK-3.

The following items are needed for startup, shutdown, or other nonproduction modes of operation:

2.1.2.2.6 FV-20/FV-21: blocks the caustic water fill to TK-2/TK-3.

An alternate decomposition to guard against circuit failure is to use one caustic water tank and two pumps. An alternate technology to maintain caustic water strength is to continuously refresh and purge the circuit as discussed previously in Caustic Reaction, paragraph 2.1.2.

2.1.2.3 DUCT HEATER

The objective of DUCT HEATER is to maintain nitroglycerin safely in the gas phase between DRYING BAY and MULTITRAY COLUMN. The technology used is to maintain duct walls at a temperature above the dew point for the relative humidity of nitroglycerin in the air stream. Allocation of objectives and constraints, using the specified technology, results in the following implementation (fig. 3):

2.1.2.3.1 HWH: provides hot water heat.

2.1.2.3.2 HX-2: transfers heat from hot water to duct walls.

2.1.2.3.3 FV-31: diverts hot water to HX-2.

The following coordination is required between these subfunctions:

a. HWH must supply a sufficient volume of hot water for HX-2 to maintain the duct wall temperature above the nitroglycerin dew point.

b. FV-31 diverts only as much hot water to HX-2 as required.

2.2.2.1 PACKED COLUMN

The objective of PACKED COLUMN is to establish physical contact between the air stream and cold water. The technology used is a packed absorber. Allocation of objectives and constraints, using the specified technology, results in the following implementation (fig. 3):

2.2.2.1.1 SA-1: provides cold water wetted packing through which an air stream passes.

2.2.2.1.2 FV-10: throttles the cold water flow to SA-1.

2.2.2.1.3 FV-11: throttles the solvent solution flow from SA-1 to prevent flooding of bottoms.

2.2.2.1.4 P-8: provides a drive for the transfer of the solvent solution from SA-1.

2.2.2.2 BATCH ACCUMULATION

The objective of BATCH ACCUMULATION is to average the solvent solution composition fluctuations from PACKED COLUMN for compatibility with existing recovery methods. The technology used is a two-stage holdup. Allocation of objectives and constraints, using the selected technology, results in the following implementation (fig. 3):

2.2.2.2.1 TK-5/TK-6: provides a primary/secondary solvent solution holdup.

2.2.2.2.2 FV-14/FV-15: blocks the solvent solution draining of TK-5/TK-6.

2.2.2.2.3 P-9/P-10: provides a drive for the transfer of the solvent solution from TK-5/TK-6.

The following items are needed for startup, shutdown, or other nonproduction modes of operation:

2.2.2.2.4 FV-12/FV-13: selects a sequential configuration of TK-5/TK-6.

ADDITIONAL FUNCTIONS AND COORDINATIONS

The following functions and coordinations are not derived directly from the proceding decomposition of processing transformations. They represent a reconsideration of the overall facility guidelines of safety and economy as applied to the derived system.

A. POLLUTION ABATEMENT BYPASS

The objective of POLLUTION ABATEMENT BYPASS is to divert the output air stream from HOT AIR DRY (1.) past POLLUTION ABATEMENT (2.) when the abatement treatment is not needed or cannot be provided. POLLUTION ABATEMENT BYPASS is accomplished with FV-29. (Caution must be exercised in the valve and operation sequencing to avoid duct collapse. The BYPASS may even be a separate exhaust port from the bay.)

B. SOLVENT REMOVAL BYPASS

The objective of SOLVENT REMOVAL BYPASS is to divert the output stream of nitroglycerin-free air from NITROGLYCERIN REMOVAL (2.1) past SOLVENT REMOVAL (2.2) when the solvent content is within environmental specifications and removal is uneconomical. In order to avoid the upset of CAUSTIC REACTION (2.1.2) when the bypass is used, the bypass ductwork must give a back pressure roughly equivalent to that of SOLVENT ABSORPTION (2.2.2). SOLVENT REMOVAL BYPASS is accomplished with FV-30.

C. BAY INTERNAL PRESSURE

The MILITRAY COLUMN operation (2.1.2.1) draws air from DRYING BAY (1.2.3). HOT AIR SUPPLY (1.1) feeds air to DRYING BAY (1.2.3). To help meet the DRYING BAY constraints of minimal air stream loss to the atmosphere and minimal propellant handling hazard, a slight negative pressure (with respect to atmosphere) can be maintained in the bay. This is done by using the MULTITRAY COLUMN operation to establish the air flow rate and throttling the HOT AIR SUPPLY rate according to the DRYING BAY pressure.

IV. CONTROL DESCRIPTION

The statement of control system functional criteria for the modernized Forced Air Dry module is based on an operational analysis of this module. That analysis organizes all the elemental functions of the system into coherent groups having well-defined objectives and a few specific states of operation connected by simple transitions. (Generally, such a scheme of aggregation also results in groups having minimal interactions with one another. Interactions are both process stream connections and control information connections.) Each of these groups is called an operational block. Operational blocks can themselves be organized into higher level operational blocks having well-defined objectives and a few specific states of operation. Operational blocks thus come under control of some higher level block, and, in turn, execute specified transitions or maintain specified states of operation by exerting control over lower level blocks.

This aggregation/decomposition of operations gives rise to a description of the system in terms of an operational hierarchy. The levels in this hierarchy describe the operations of the system at different levels of abstraction. High-level operations coordinate abstract operations of different parts of the system, with little reference to the internal aspects of how these operations are carried out. On the other hand, low-level operations coordinate the monitoring of sensors and directing of actuators in the process.

The blocks in the hierarchy are given three-letter names for convenient reference. These names abbreviate an identification of the function which the block provides to the system. They are listed here with their meanings for explanation.

FAD: Forced Air Dry

DRY: Dry

CNV: Convective Heat

RAD: Radiant Heat

DBA: Drying Bay Area

BYP: Pollution Abatement Bypass

NGR: Nitroglycerin Removal

HTR: Heater

CSB: Caustic Scrub

CCT: Caustic Circulate

CSP: Caustic Solution Preparation

SRB: Solvent Removal Bypass

SVR: Solvent Removal

SVA: Solvent Absorption

SVS: Solvent storage

WCH: Water Chiller

The working notes for the operational analysis are contained in the Operational Analysis Supplement to this System Functional Criteria (Appendix). The results of that analysis are presented in the Process Control Diagram (fig. 3), the Event Correlation Diagram (figs. 4 and 5), and the Control Information Flow Diagram (figs. 6 and 7). These three diagrams provide three orthogonal representations of the system. The Process Control Diagram summarizes the processing equipment to be used and specifies the process stream interconnections. The necessary control instrumentation on the equipment and streams is also shown. The Event Correlation Diagram gives a complete logical partitioning of the operational steps required to move the system through all required processing states. The Control Information Flow Diagram shows all control activities which are origins or destinations of data and indicates the control data which they use.

Every attempt has been made to avoid prejudicing any control system design decisions by refraining from making specific statements regarding implementation. The goal here is to functionally identify the minimal system of controls which can direct the operation of the process described in Section III, Process Description, according to the goals discussed in Section II, Operational Goals. The diagrams graphically display this functional identification. This

section describes that graphical display and discusses the functional sufficiency of the criteria contained there.

Both the operational analysis and the resulting functional criteria statement describe the facility from the viewpoint of faultless operation. Excluding operator error, failures in the facility are due to failures in process equipment or control equipment. Here, "failures" can mean either the occurrence of an unexpected event or nonoccurrence of an expected event. The impact of such failures must be measured either against facility goals of safety, economy, reliability, availability, and maintainability or against the functional criteria statement of success. A significant effort to be made in design is the identification of failure points, the probability of failures there, the propagation of the failure, the unambiguous detection of the failure, and additional process or control equipment which can be used to overcome the problem. Until then, any attempt to identify possible faults and possible methods of their correction is an exercise in speculation.

A. The Process Control Diagram (fig. 3)

The Process Control Diagram is the equivalent of a preliminary Piping and Instrumentation Diagram. It represents the functional concept of the pilot facility in concrete terms. Equipment tags are created for reference in this analysis and are independent of any prior nomenclature. Tags representing sensors, valves, and motor controls are also created in accord with ANSI Y32.20 - 1975 naming conventions for reference in this analysis. All instrumentation is to be interpreted generically as to its functional representation. For example, a tag labeled "FE" indicates a source of flow data. Design activity must determine a viable means for providing that data. In another example, if a stream must be diverted between two connections, a two-way diverter valve is shown, although design may call for several separate valves in the actual piping.

B. The Event Correlation Diagram (figs. 4 and 5)

A major thrust of operational analysis is to decompose the complexity of facility operation and isolate sequences of operations having simple, well-defined relationships with other sequences of operations. This decomposition enables a criteria specification to be comprised of numerous simple operation sequence descriptions rather than one complex operation description. The Event Correlation Diagram is a concise statement of these sequence descriptions and their organization into facility operation. This two-page diagram successively shows more detailed step sequences whose aggregate accomplishment moves the facility from one state to another. The first page provides an overview of the facility's operation in terms of its five major operational blocks and their subblocks. The second page provides possible sequences for performing every required subblock step in terms of control instrumentation.

Several representation conventions have been used in this diagram with regard to operation naming, sequence permissives, and sequence nesting. States of operational blocks are named between a pair of vertical lines. Transitions of

operational blocks are named in parentheses on lines connecting state identifiers. Transitions of the facility are shown as a double line connecting facility states, transitions of Level 1 operational blocks are shown as single lines, and transitions of Level 2 operational blocks are shown as dashed lines.

An important concept in operation sequences is that of the permissives which must be satisfied before an operation is performed. These are indicated on the diagram with pairs of vertical lines which enclose final states of subblocks which have completed transitions and initial states of subblocks which are to start transitions. The interpretation of these collections is that all indicated final states must be reached before the new transitions can be initiated.

Successive decomposition of operation sequences and corresponding aggregation is indicated as follows on the diagram. The system states and transitions are indicated across the top of the first page. System operations have an alternative in the UNLOAD state, so both transitions from UNLOAD are shown. The three-letter abbreviations for Level 1 and Level 2 operational blocks are arrayed down the left margin of the diagram. The sequence of states and transitions of Level 1 blocks which combine to yield the states and transitions of the facility are indicated and correlated by checkpoint where necessary. Details of states and transitions for Level 1 blocks are provided by showing the states and transitions of any Level 2 blocks which compose it. The "isolated" nature of these states and transitions has the result that no matter when or how often a given transition of a specific operational block is used, it is always the same transition, performed in the same manner. For example, the operation of STARTUP of Nitroglycerin Removal is independent of whether it is performed at facility STARTUP or at facility RESUME.

Ultimately, all operation sequences must be performed by sensing process conditions and actuating process equipment. For every nondecomposed state and transition which appears on the first page, an explanatory chart on the second page furnishes an interpretation of the state and sequence into steps using sensor inputs or actuator outputs. This establishes the need for and use of most components constituting the minimal instrumentation shown on the Process Control Diagram (fig. 3). The remaining sensors are needed only for data collection. Acquisition and recording requirements are documented in the Operational Analysis Supplement.

C. The Control Information Flow Diagram (figs. 6 and 7)

The Control Information Flow Diagram is a summary of all information sources and uses in the operation of the facility. Control actions such as level control, sequencing, and multivariable selection are indicated by labeled circles. Lines from the top of a diagram identify data to be provided by a higher level activity, lines from the bottom of the diagram identify data to be obtained from a lower level activity, and lines to the bottom of the diagram identify actuation signals. Engineering- or management-specified parameters which are to be used for establishing an operating point are identified by data lines from the upper left corner box labeled "par." Data to be recorded for management use or

engineering analysis are identified by data lines to the upper right corner box labeled "rec." The activity circles are labeled according to ANSI Y32.20 - 1975, with user choices defined at the bottom of the sheet. Again, note that the indicated sensors and actuators are meant in a generic sense, with actual methods to be developed by a design activity. A special case is the activity labeled with "*." This shows the generation of some lower level actuation triggered either by the receipt of some indicated data or else by the execution of some procedure sequence in open-loop operation. Most of these sequences can be inferred from the Event Correlation Diagram (figs. 4 and 5). Further clarification is available in the Appendix (Operational Analysis Supplement).

D. Conclusions

A data logging system has been procured for the prototype plant control system that should be used for verifying control and recording results of operations identified in this criteria. Loop coordinations are traditional in form and can be carried out by any class of standard proportional-integral-derivative mode control. Sequencing of operations poses no special demands. Design will develop interlock requirements and any special operation sequences which may be required.

This functional criteria has identified the minimal control system necessary for effective operation of the currently configured modernized Forced Air Dry prototype plant. The operational analysis for the single bay system is as complete as the known facts allow. When pilot plant results are available, any resolutions of the various outstanding questions can be readily incorporated in the analysis to develop a final description of the single bay system. This description will provide the basis for a detailed criteria development for a multibay production facility.

V. DISCUSSION

The operational analysis of the modernized Forced Air Dry pilot plant has identified a number of discrepancies between project goals and pilot plant implementation. Identification of these discrepancies is critical if the prototype plant is to meet the project goals. As discussed in the following paragraphs, these discrepancies bear directly on the adequacy of the project as an MM&T activity.

1. Caustic scrubbing of nitroglycerin is to be accomplished with a sieve tray column using a caustic water downflow against air stream exhaust upflow. Nitroglycerin vapor in the air stream is to be decomposed into harmless by products and absorbed into the liquid phase. The major independent variables influencing the process in this column are rate of air flow (contact time), air and caustic water temperatures (Boltzmann kinetic factors), and caustic water strength (mass action factor). Since the process configuration to be used does not provide for setting the caustic water temperature at different operating points, the pilot operation is unable to determine the effect of this variable on

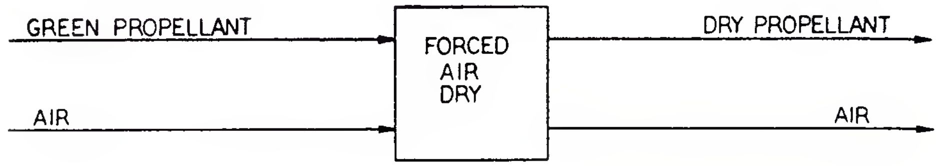
the process. The selected configuration is subject to relatively large changes in the operating point due to the wide seasonal changes in the ambient temperature of the caustic water. In fact, low winter temperatures are the justification for having a bypass around the solvent absorption water chiller, suggesting that the caustic water will be quite cold in winter, thereby, accentuating premature removal of solvent from the air stream in the caustic scrubber. A controlled environment for prototype plant studies must be established since not enough is known about this process step to leave it uncontrolled. Only by collecting valid data on prototype operation can engineering tradeoff studies be made on the economic aspects of the production facility design. Specifically, some means of caustic water temperature maintenance must be provided. Otherwise, pilot plant tests will not furnish any data from which a valid correlation can be developed between caustic water temperature and nitroglycerin removal effectiveness. Some heat may be available from excess duct heater capability, but that operation cannot be directed for temperature maintenance of the caustic water; it must be used to guarantee no nitroglycerin condensation in the bay-to-scrubber air duct. Various issues which need to be balanced are heating costs, caustic water strength, effective nitroglycerin removal, and the capability to operate at air flow rates sufficient to exhaust from more than one bay simultaneously.

2. Caustic water is to be supplied to the caustic scrubber through a circulation loop consisting of a reservoir and a pump. Protection against failure in the loop is provided by duplicating the reservoir and pump. The alternate circuit also provides extra caustic water in case the strength of the primary caustic water degrades too much for effective nitroglycerin decomposition. Not enough is known about the caustic water requirements to omit the establishment of a controlled environment for prototype plant studies. Only by collecting valid data on prototype operations can engineering tradeoff studies be made on the economic aspects of production facility design. Specifically, the use of a continuously degrading caustic water batch will not allow the development of correlation between caustic water strength and caustic scrubbing effectiveness. A continuous purge of used caustic water and refresh with new solution would maintain a steady composition in the circuit and would also remove many of the decomposition product solids from the loop to minimize potential sieve plugging. The alternate caustic reservoir could be used to supply the refresh stream, or it could be entirely eliminated, with refresh furnished directly from the caustic solution preparation tank. The alternate pump would be used as a spare to the circulation loop. Some issues influencing this tradeoff are the cost of continuous supply, the preparation of large caustic solution batches, the allowable solution degradation, the potential downtime from column plugging, solution strength variation due to water loss, and the amount of nitroglycerin contamination remaining in the scrubber exhaust.

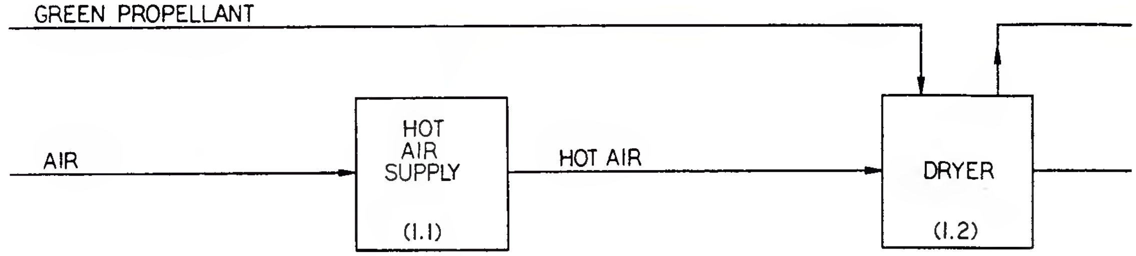
3. Solvents are removed from the air stream by absorption into cold water in a packed column. The water is cooled by a chiller, or, if ambient temperature is cool enough, water is supplied directly from storage. This strategy of using an ambient temperature stream will make it difficult to use pilot operation results to establish a correlation between water temperature and solvent removal efficiency. The operational analysis assumed a temperature setpoint for the chiller. If stand-alone chiller operation is inadequate for establishing the removal process temperature in the absorber, temperature control of absorption should be obtained by dynamic variation of the chiller operation.

4. Solvent solution from the absorber is accumulated into batches in order to average composition fluctuations. There is no evidence of need for the dual tanks, pumps, and bypass piping. Pilot plant studies should determine the required averaging capacity and batch transfer cycle to be used. The only composition average which will be repeatable is obtained by accumulating solvent solution over an entire drying cycle. This is because the different solvent volatilities will cause widely varying gas phase compositions during the cycle.

5. Supply of temperature-controlled air at a constant flow rate is to be provided by dual ducting, a steam heater, a two-way air damper, and a blower. The steam heater is to be operated full on and temperature regulation is to be achieved by using the air damper to combine appropriate amounts of heated and ambient air. This arrangement appears to be less economical to build, less efficient to operate, and more complex to maintain than a single duct with variable steam heat and the same blower. Ductwork would be simpler and no damper would be required. Rate of response to temperature setpoint changes would necessarily be slower, but the rate of change required for operation is only a few degrees per hour. A cost-of-operation tradeoff study is required to evaluate the decreased cost of steam energy against the increased cost of the blower having to pull all air through the heater.



SYSTEM



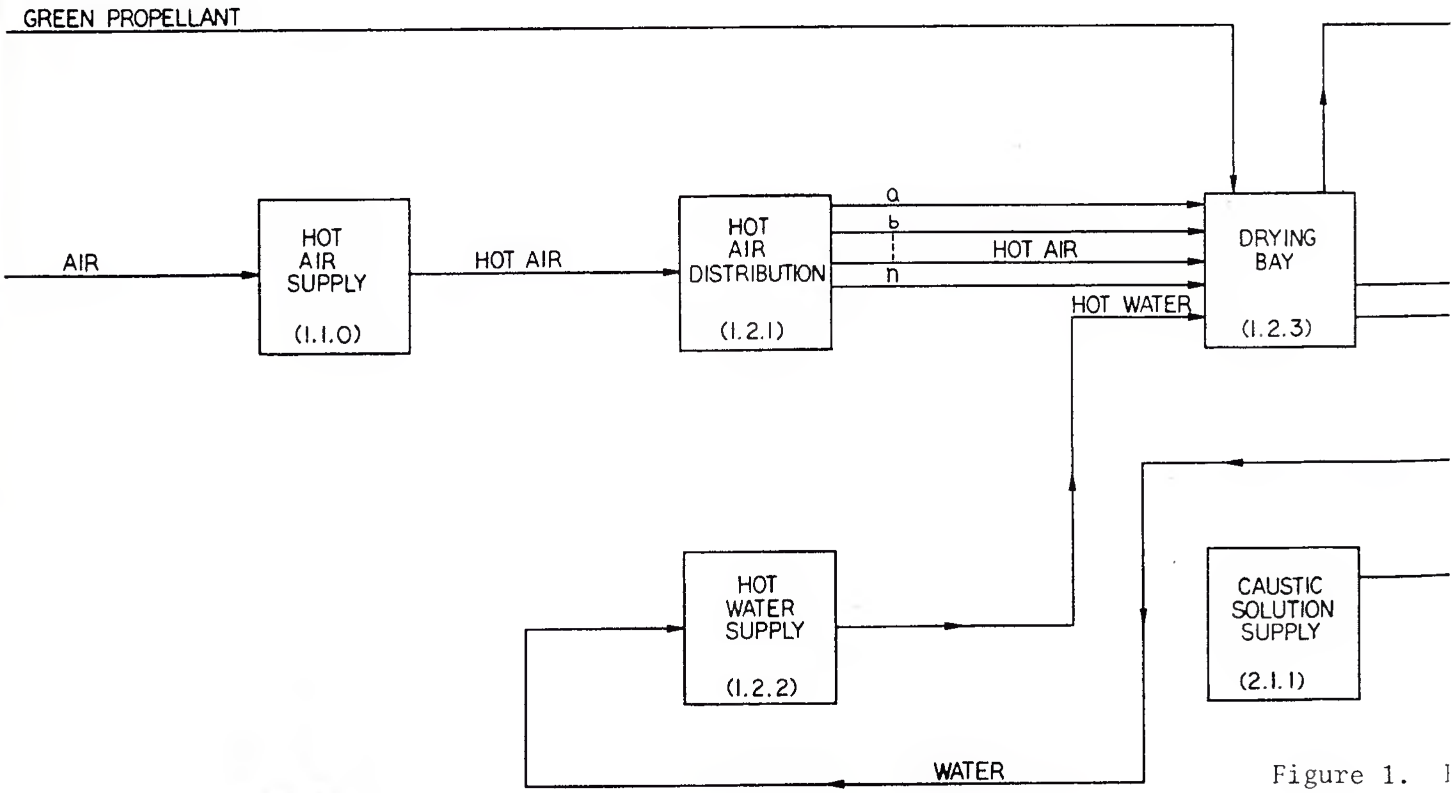


Figure 1. I

A

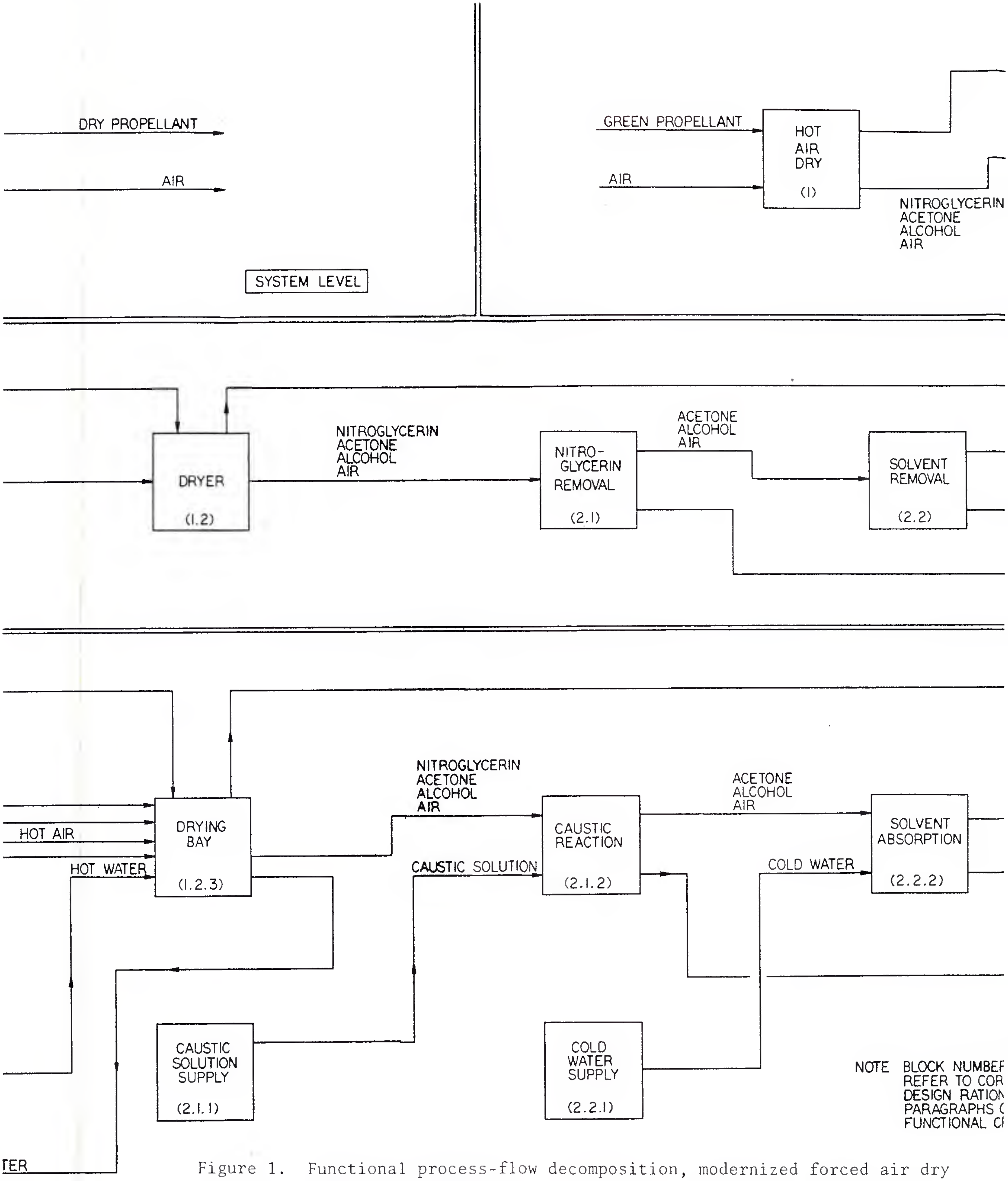
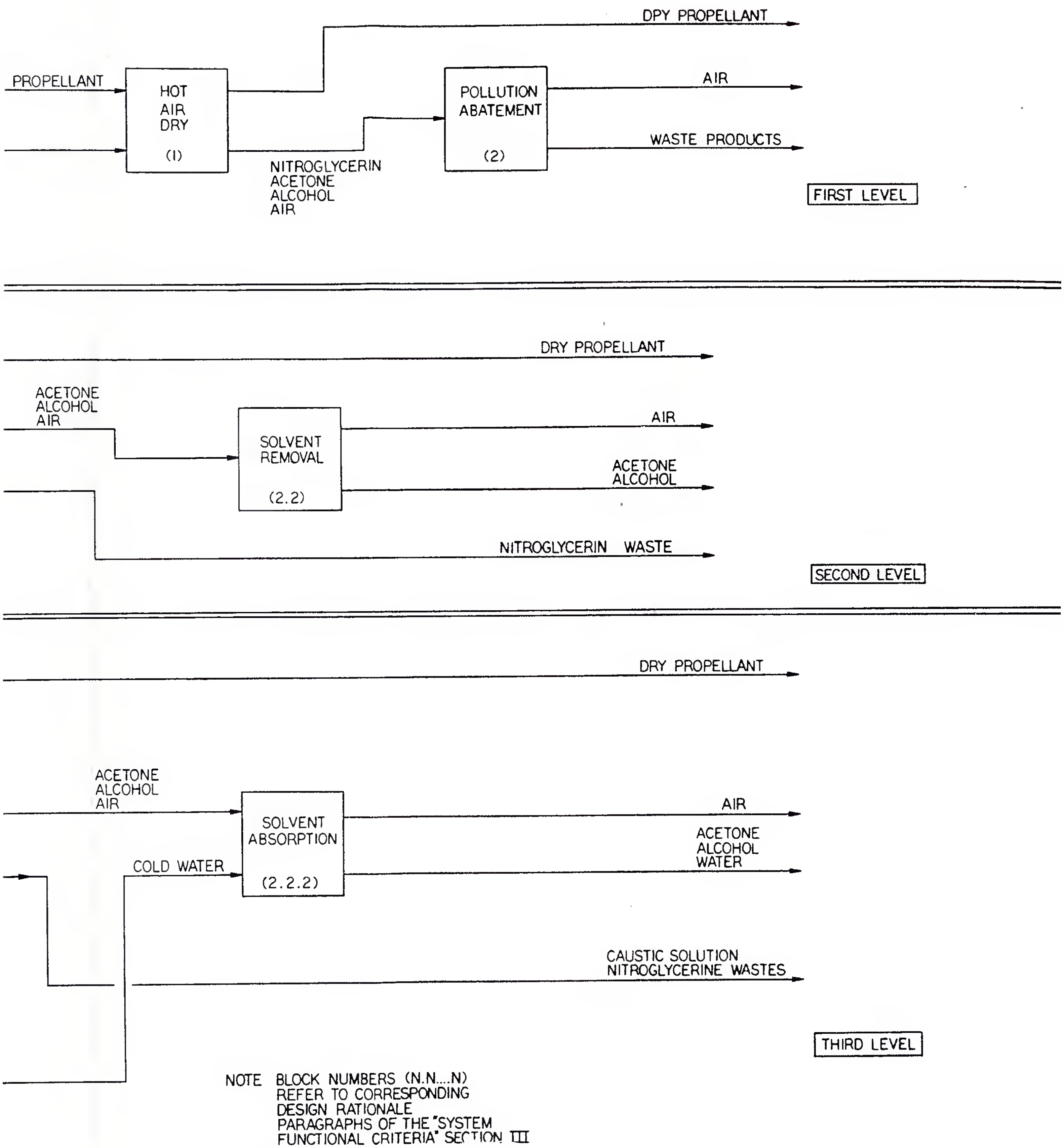
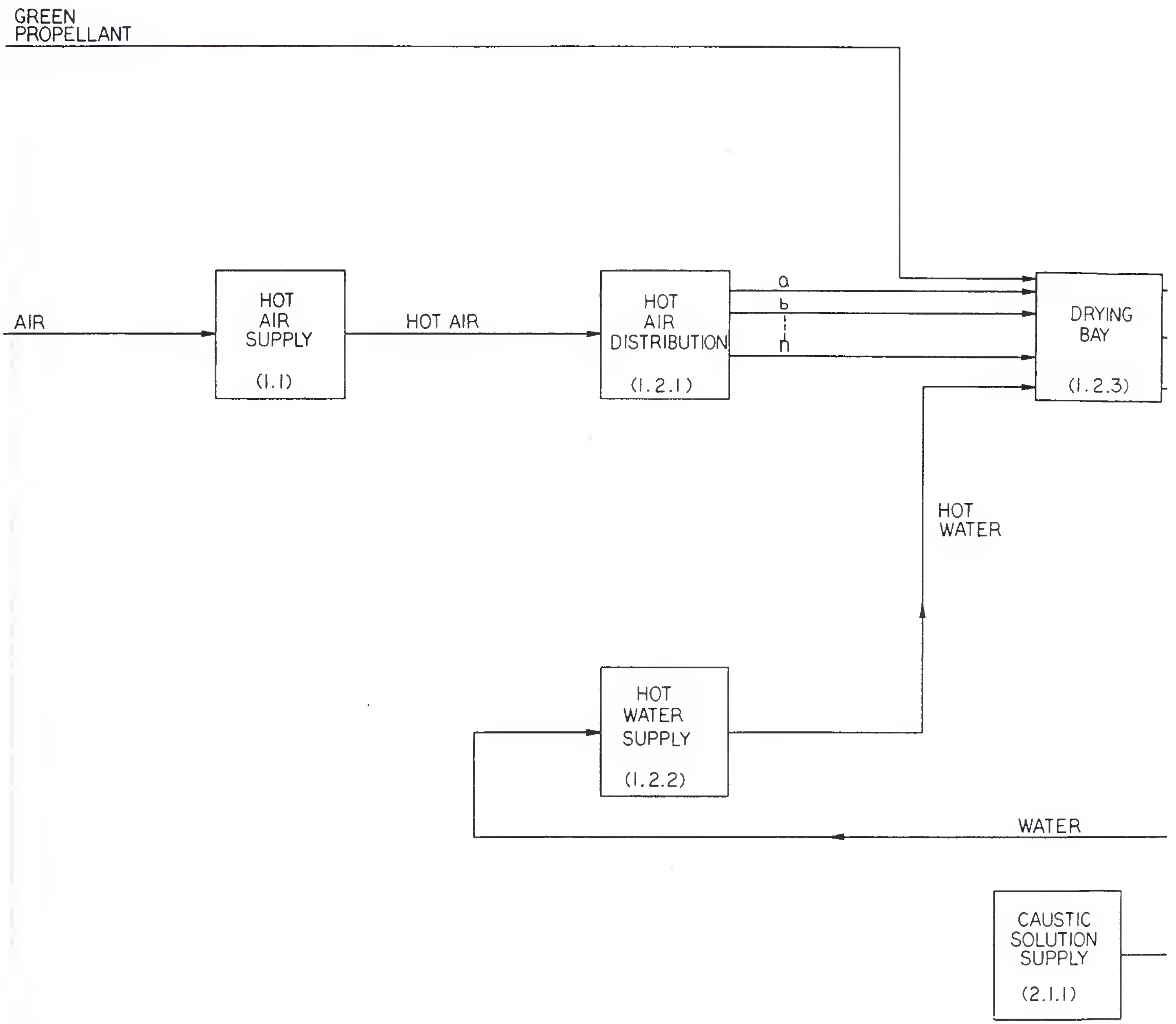


Figure 1. Functional process-flow decomposition, modernized forced air dry (levels 1 through 3)

(6)



:ion, modernized forced air dry


GREEN
PROPELLANT
AIR
HOT
AIR
SUPPLY
(1.1)
HOT AIR
HOT
AIR
DISTRIBUTION
(1.2.1)
a
b
n
DRYING
BAY
(1.2.3)
HOT
WATER
HOT
WATER
SUPPLY
(1.2.2)
WATER
CAUSTIC
SOLUTION
SUPPLY
(2.1.1)

Figure

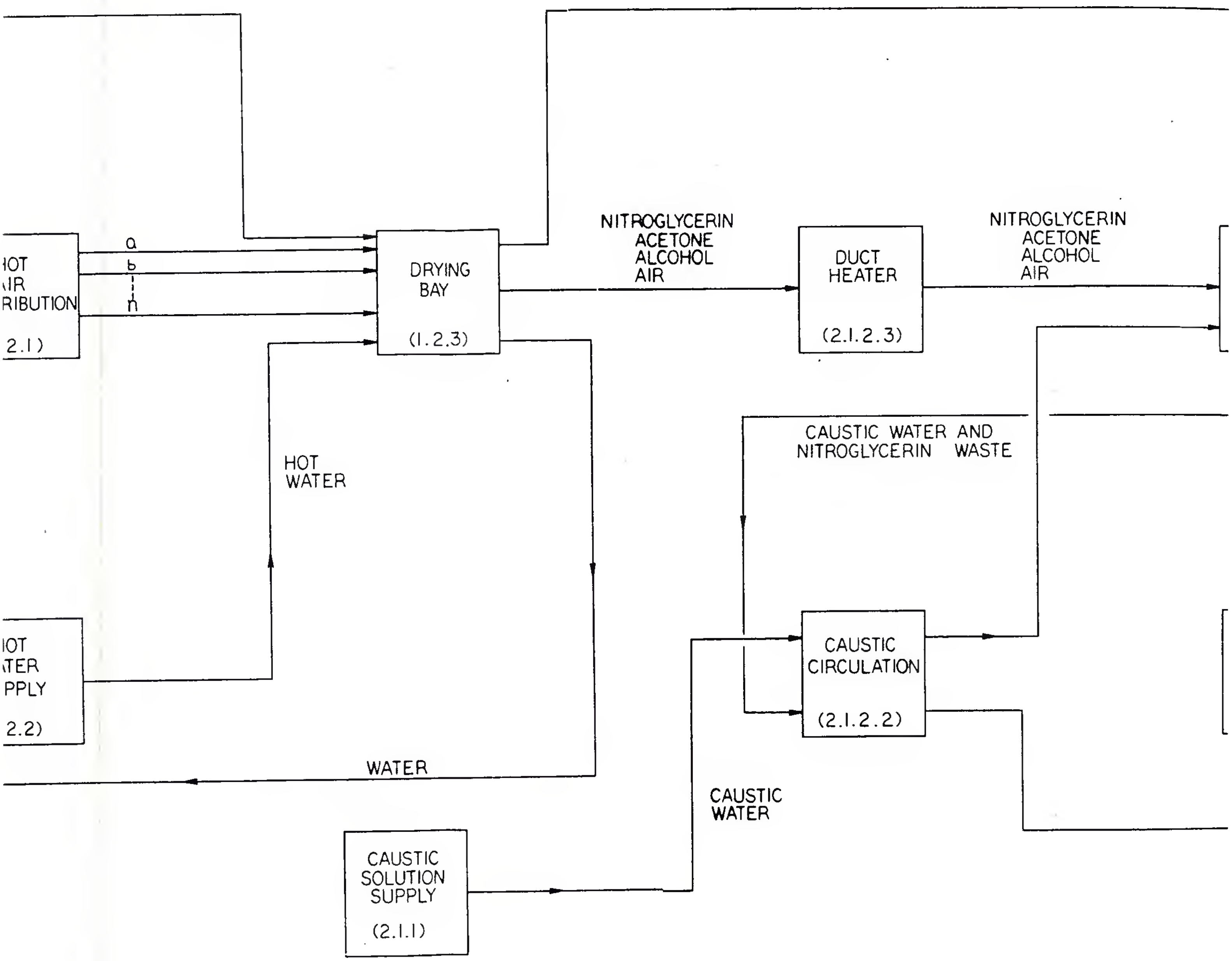
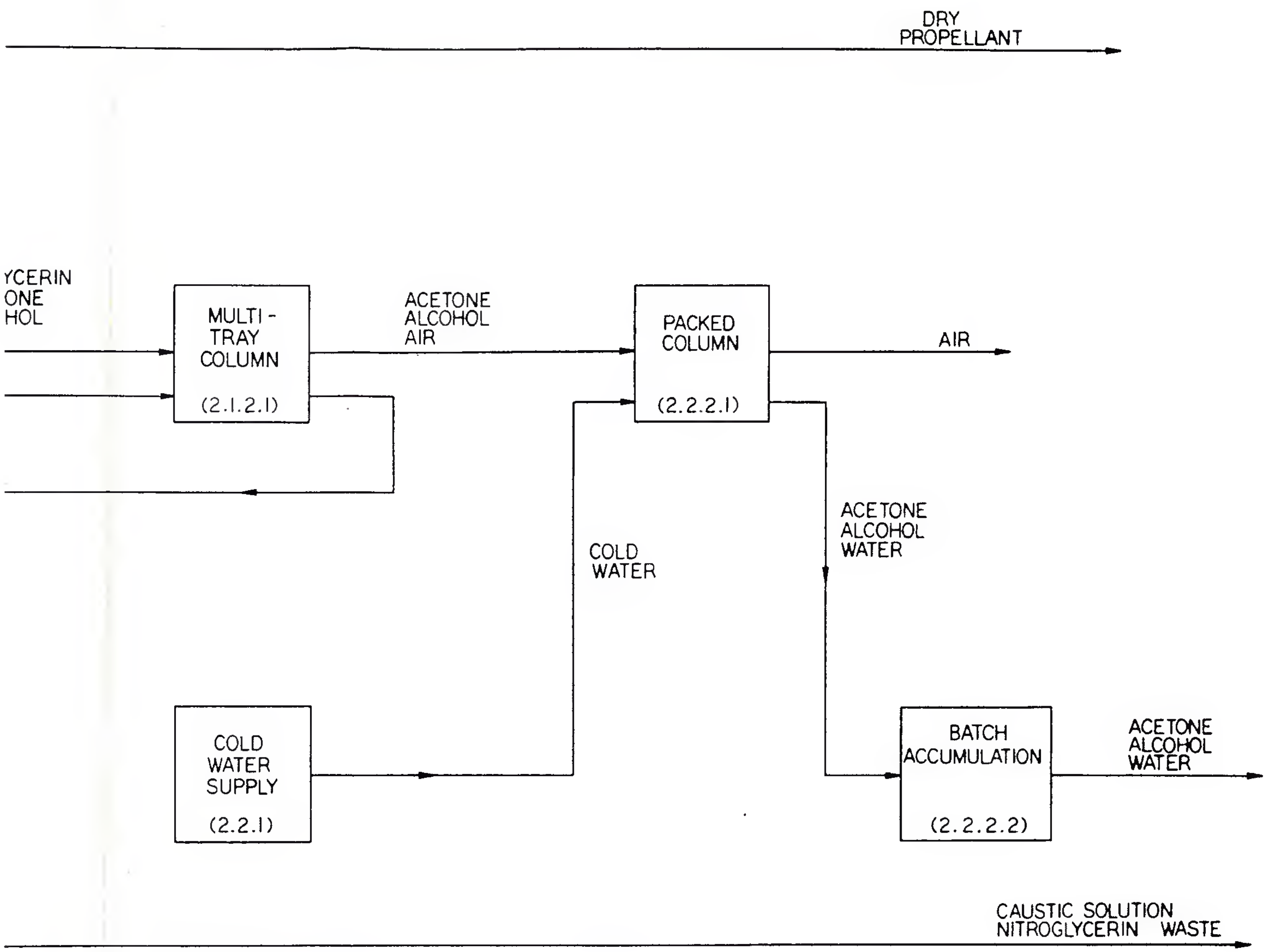


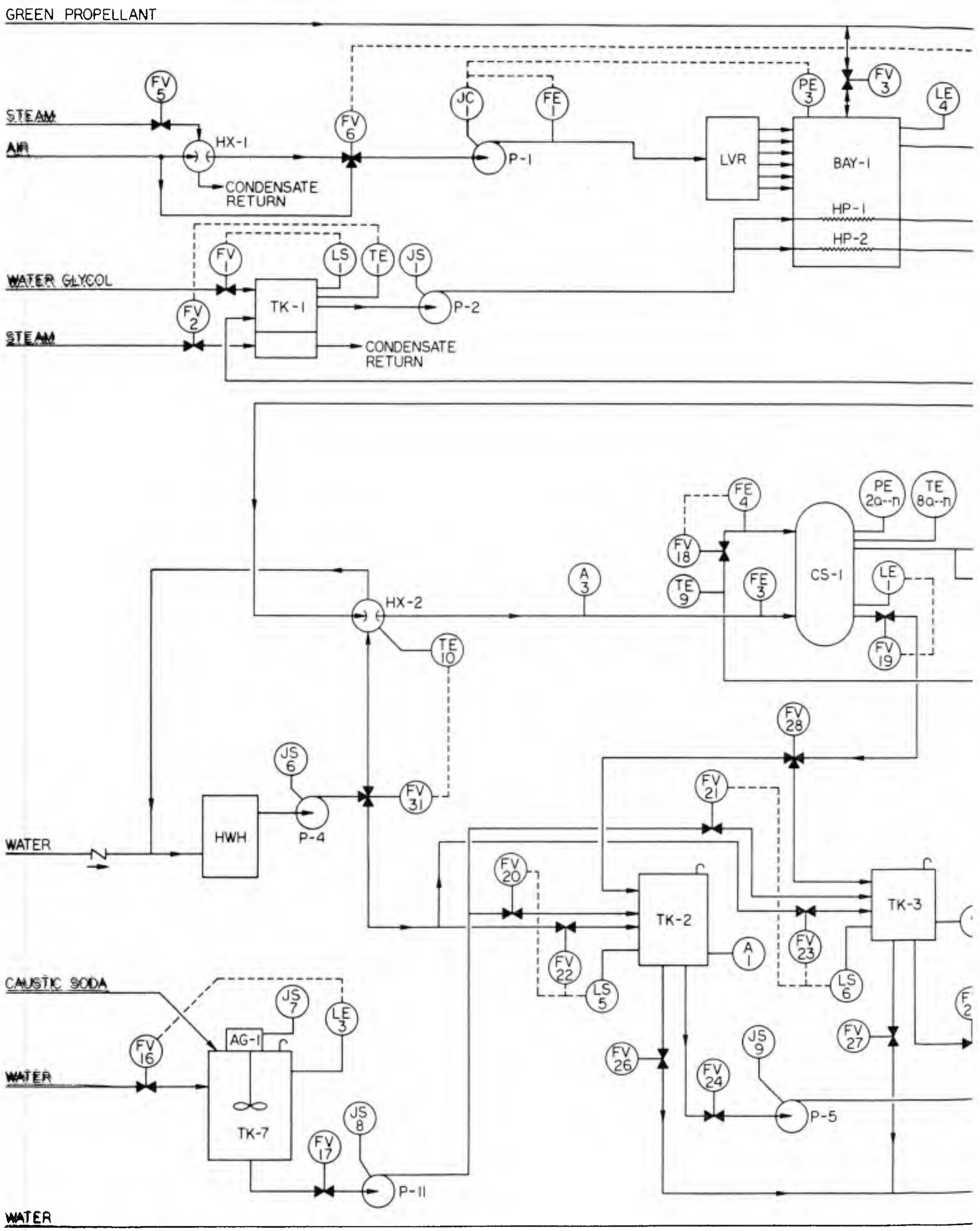
Figure 2. Functional process-flow decomposition, modernized forc
(level 4)

(b)



FOURTH LEVEL

dernized forced air dry


GREEN PROPELLANT
STEAM
AIR
HX-1
CONDENSATE RETURN
FV 5
FV 6
JC 1
FE 1
P-1
LVR
PE 3
FV 3
LE 4
BAY-1
HP-1
HP-2
WATER GLYCOL
FV 1
LS 1
TE 1
JS 1
TK-1
P-2
FV 2
STEAM
CONDENSATE RETURN
FE 4
PE 2a--n
TE 8a--n
FV 18
TE 9
FE 3
CS-1
LE 1
FV 19
A 3
HX-2
TE 10
FV 28
JS 6
FV 31
FV 21
P-4
HWH
WATER
FV 20
TK-2
TK-3
FV 22
FV 23
A 1
LS 5
LS 6
CAUSTIC SODA
JS 7
LE 3
AG-1
FV 16
WATER
TK-7
FV 17
JS 8
P-11
FV 26
FV 24
JS 9
P-5
FV 27
WATER

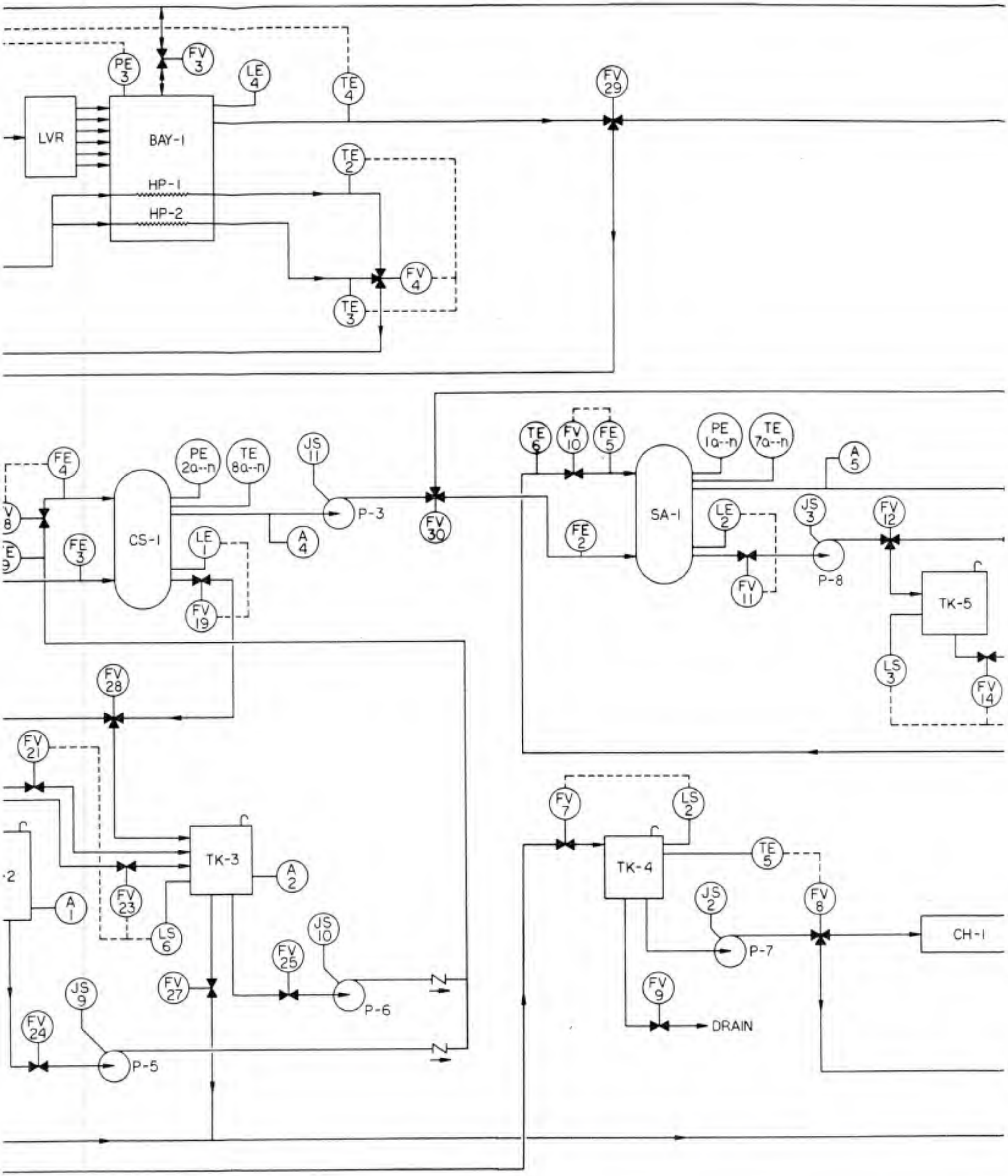


Figure 3. Process c

b

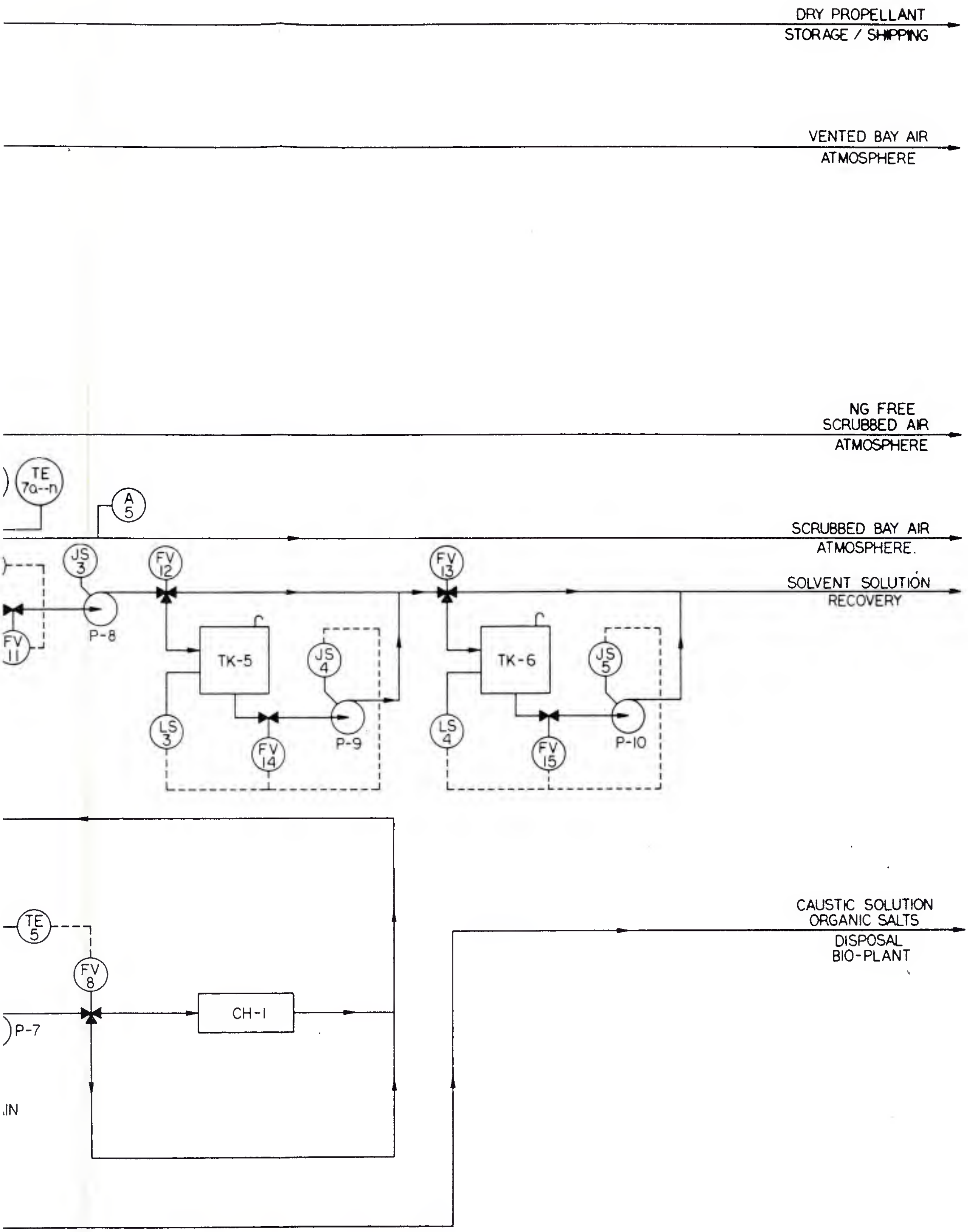
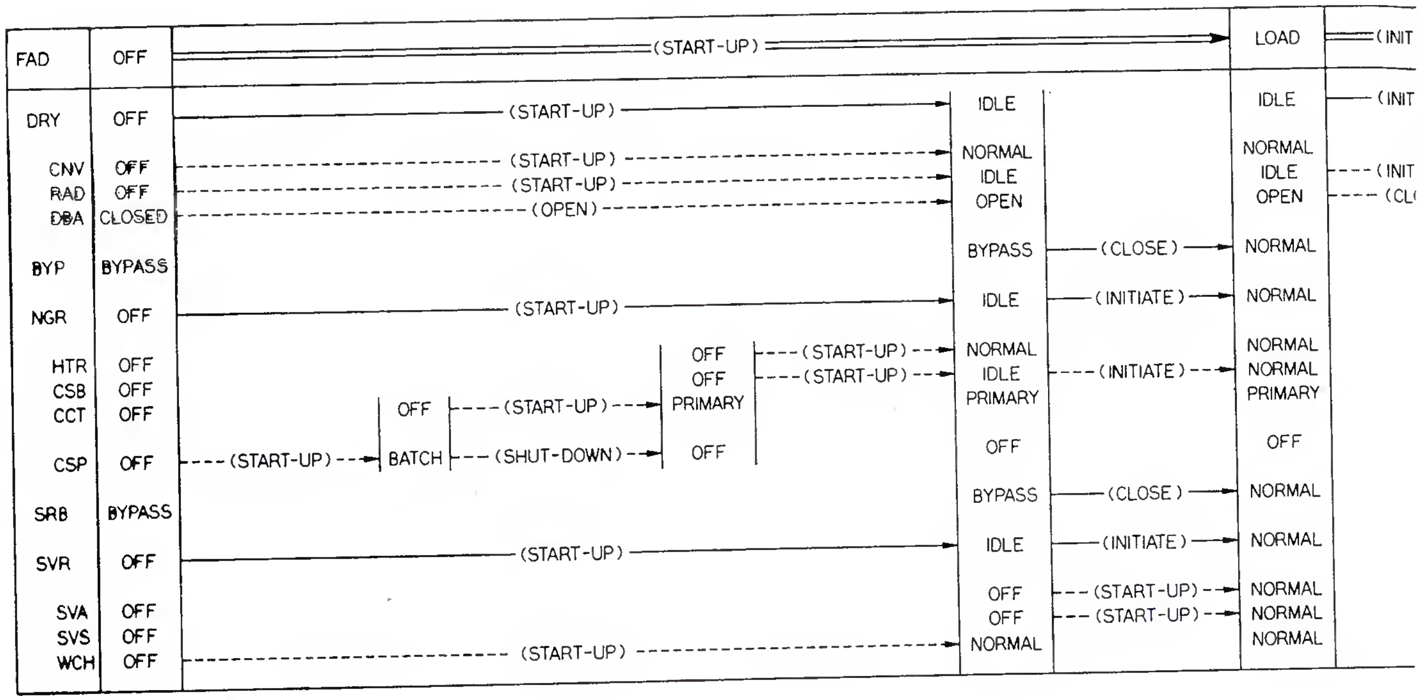
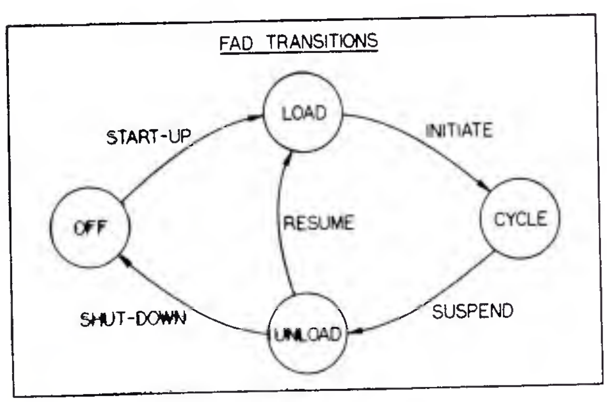


Figure 3. Process control diagram, modernized forced air dry

C/

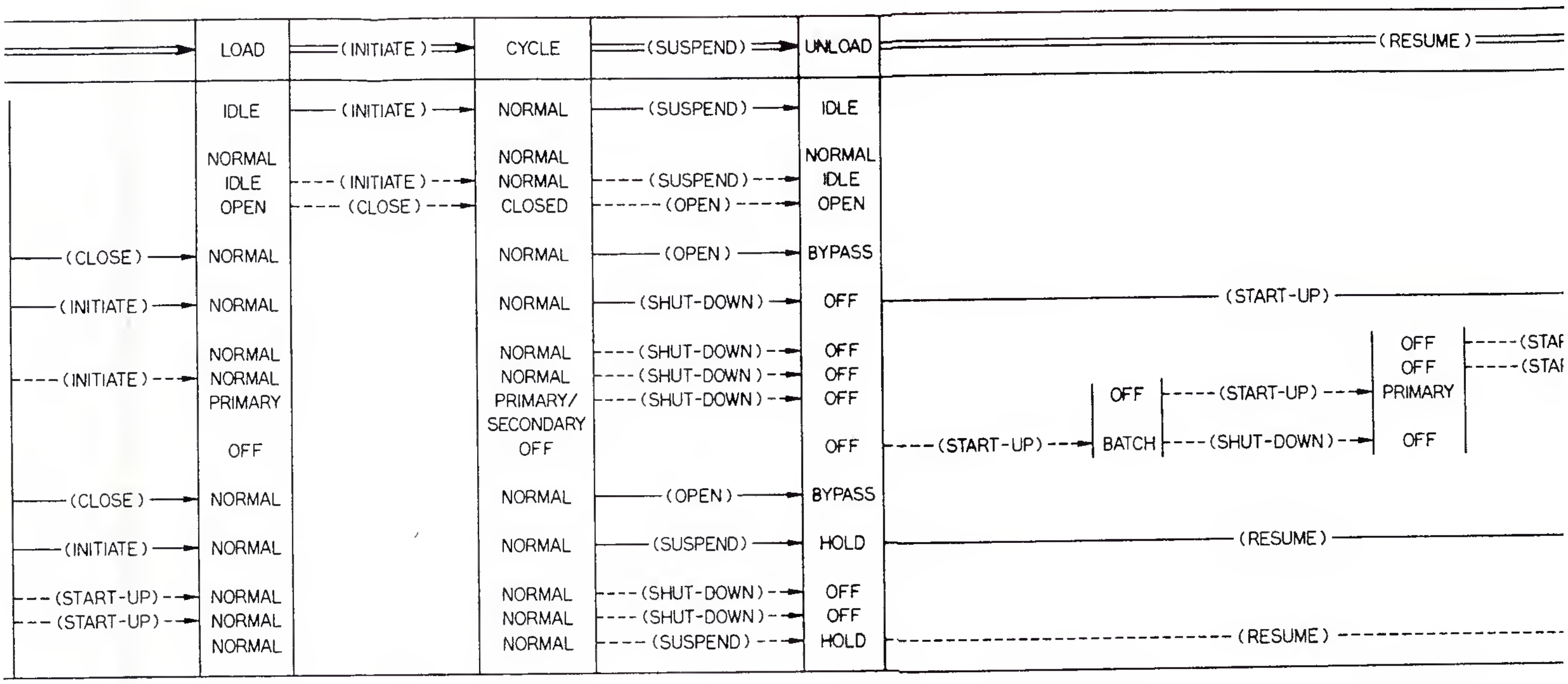




ABBREVIATIONS

FAD : FORCED AIR DRY
DRY : DRY
CNV : CONVECTIVE HEAT
RAD : RADIANT HEAT
DBA : DRYING BAY AREA
BYP : POLLUTION ABATEMENT BYPASS
NGR : NITROGLYCERIN REMOVAL
HTR : HEATER
CSB : CAUSTIC SCRUB
CCT : CAUSTIC CIRCULATE
CSP : CAUSTIC SOLUTION PREPARATIO
SRB : SOLVENT REMOVAL BYPASS
SVR : SOLVENT REMOVAL
SVA : SOLVENT ABSORPTION
SVS : SOLVENT STORAGE
WCH : WATER CHILLER

A

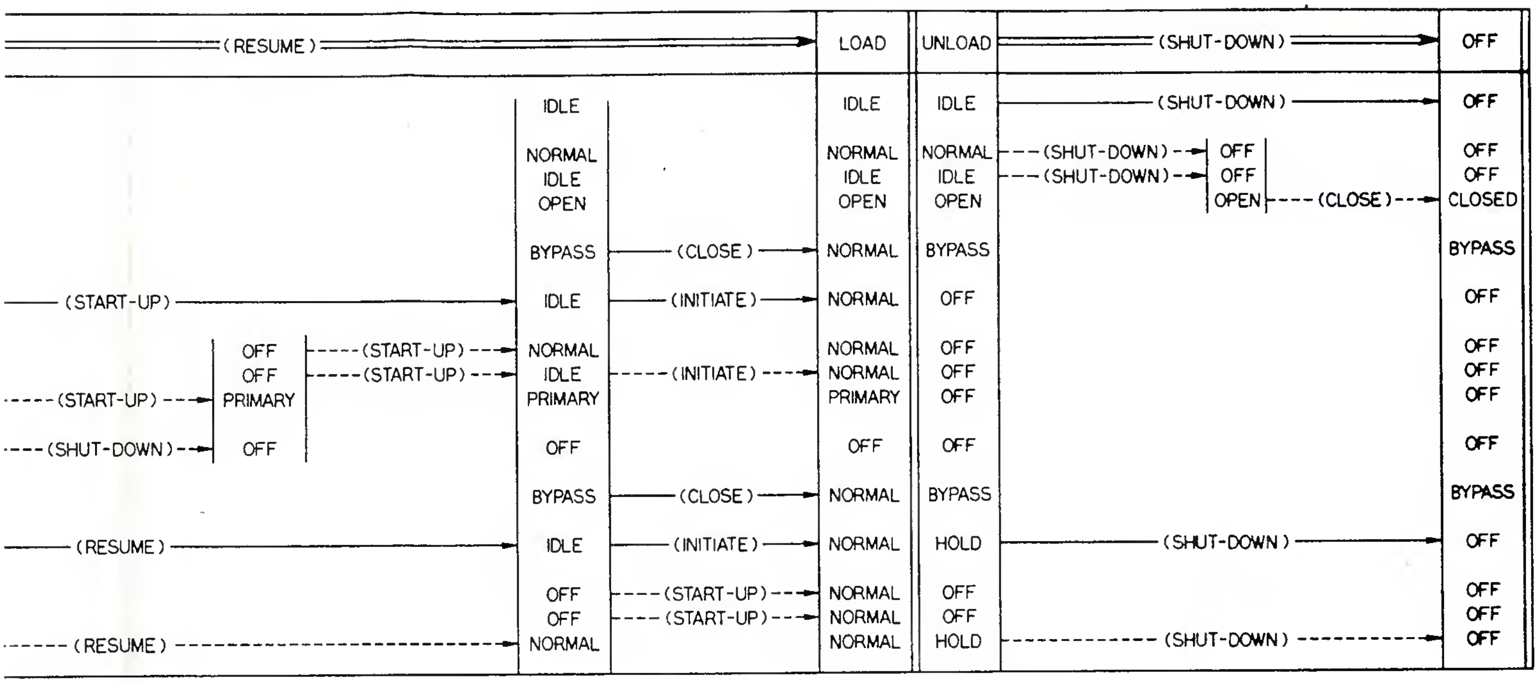


REVIATIONS

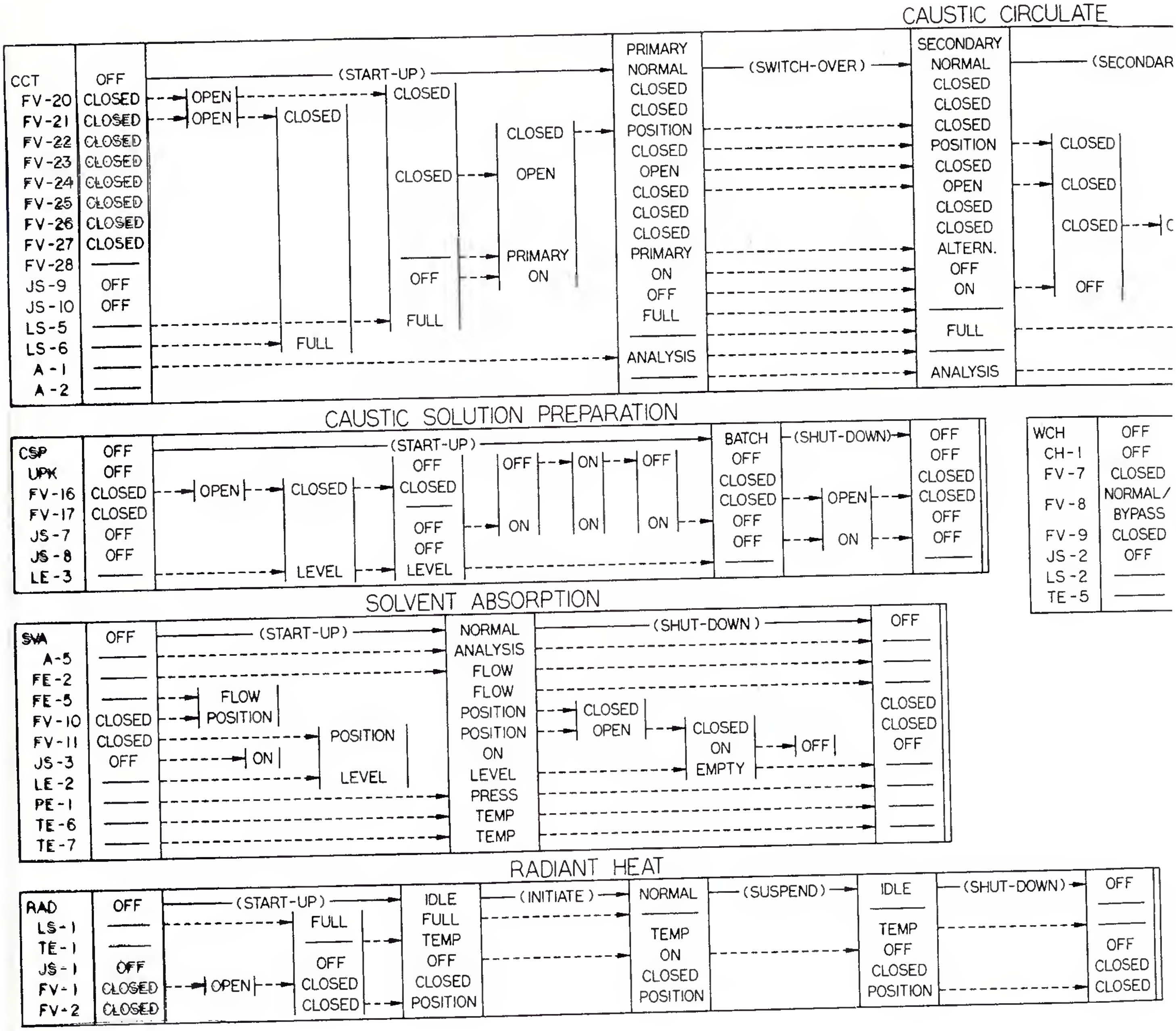
AD : FORCED AIR DRY
DRY : DRY
CNV : CONVECTIVE HEAT
RAD : RADIANT HEAT
DBA : DRYING BAY AREA
BYP : POLLUTION ABATEMENT BYPASS
NGR : NITROGLYCERIN REMOVAL
HTR : HEATER
CSB : CAUSTIC SCRUB
CCT : CAUSTIC CIRCULATE
CSP : CAUSTIC SOLUTION PREPARATION
SRB : SOLVENT REMOVAL BYPASS
SVR : SOLVENT REMOVAL
SVA : SOLVENT ABSORPTION
SVS : SOLVENT STORAGE
WCH : WATER CHILLER

Figure 4. Event correlation diagram, modernized forced

6



ıgram, modernized forced air dry (operation)



CAUSTIC CIRCULATE
CCT
FV-20
FV-21
FV-22
FV-23
FV-24
FV-25
FV-26
FV-27
FV-28
JS-9
JS-10
LS-5
LS-6
A-1
A-2
(START-UP)
PRIMARY NORMAL
(SWITCH-OVER)
SECONDARY NORMAL
(SECONDAR
CAUSTIC SOLUTION PREPARATION
CSP
UPK
FV-16
FV-17
JS-7
JS-8
LE-3
(START-UP)
BATCH
(SHUT-DOWN)
WCH
CH-1
FV-7
FV-8
FV-9
JS-2
LS-2
TE-5
NORMAL/ BYPASS
SOLVENT ABSORPTION
SVA
A-5
FE-2
FE-5
FV-10
FV-11
JS-3
LE-2
PE-1
TE-6
TE-7
(START-UP)
NORMAL
(SHUT-DOWN)
RADIANT HEAT
RAD
LS-1
TE-1
JS-1
FV-1
FV-2
(START-UP)
IDLE
(INITIATE)
NORMAL
(SUSPEND)
IDLE
(SHUT-DOWN)

Figure 5

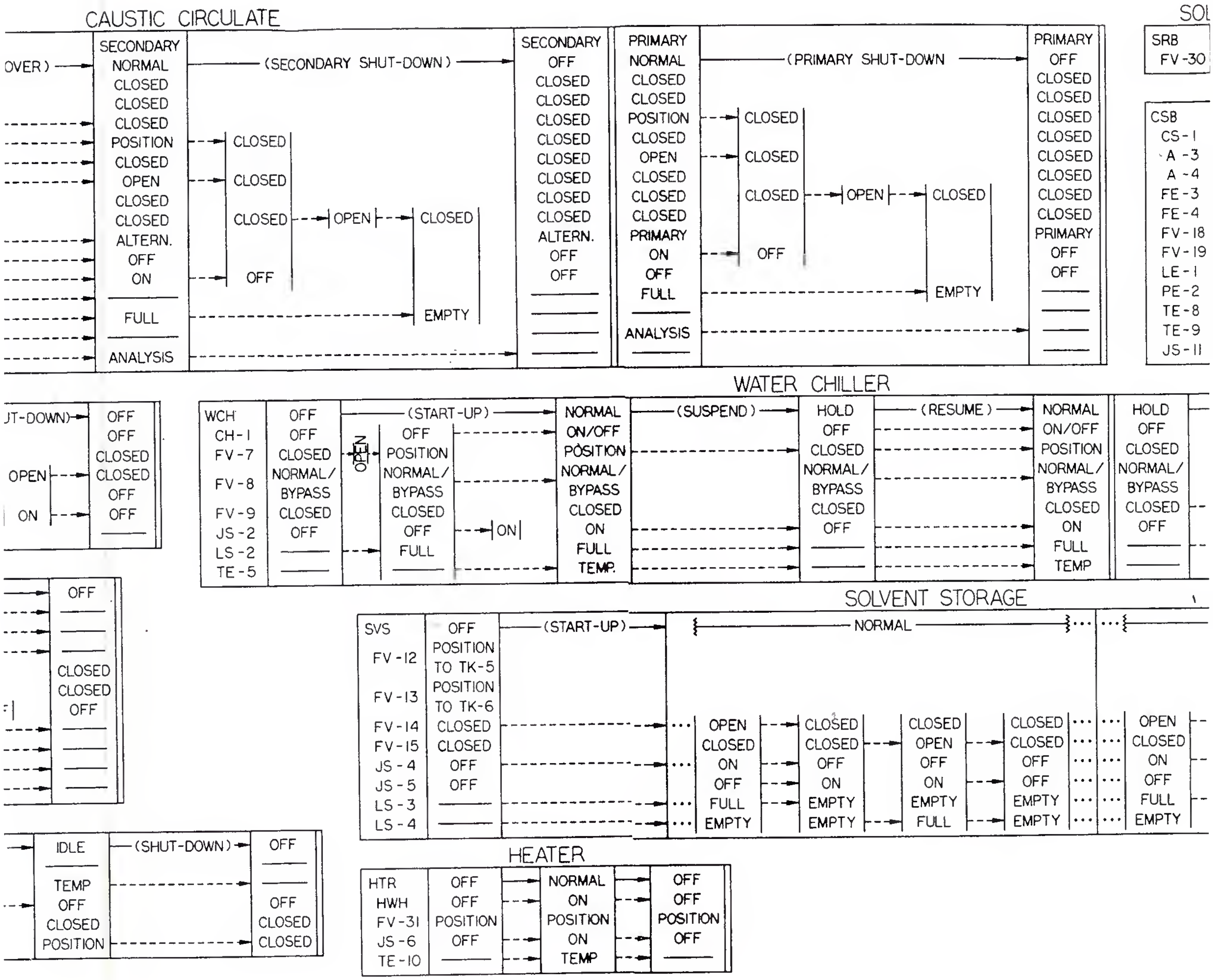
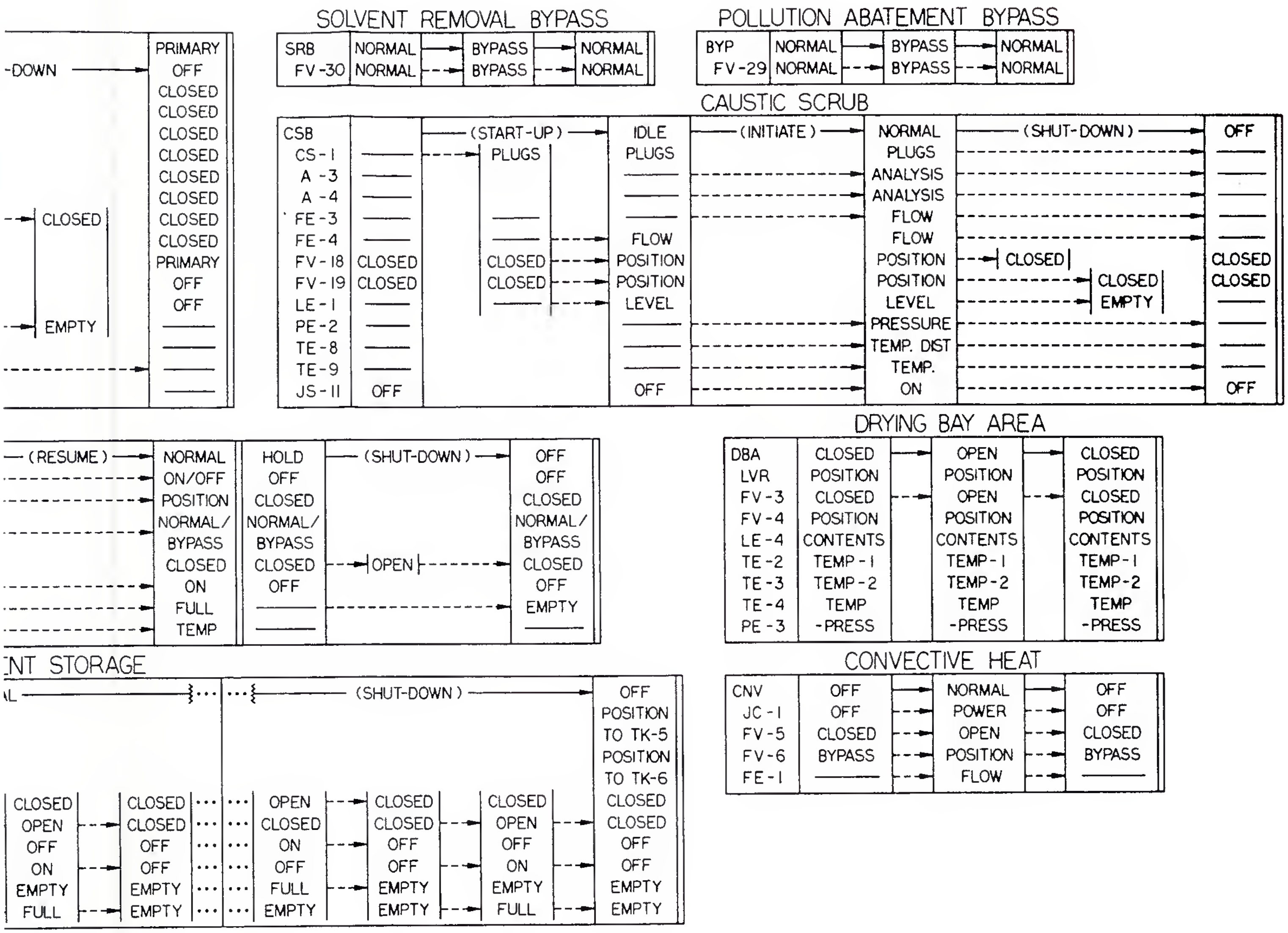


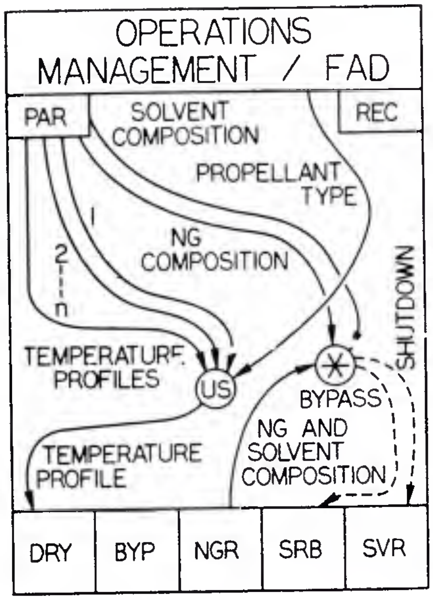
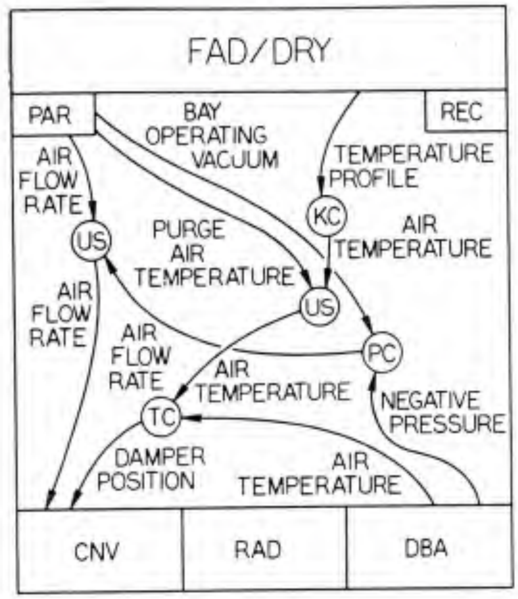
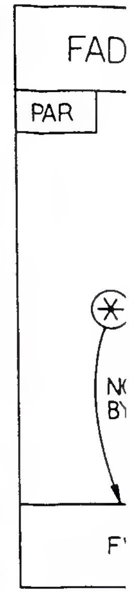
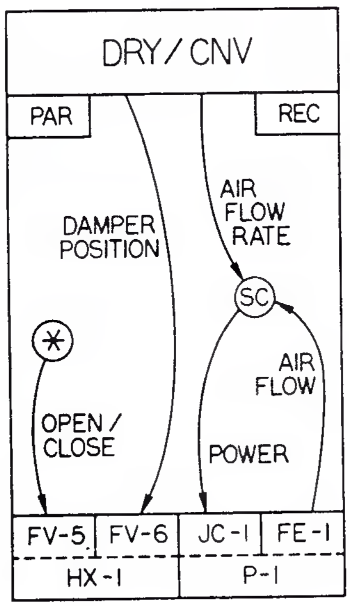
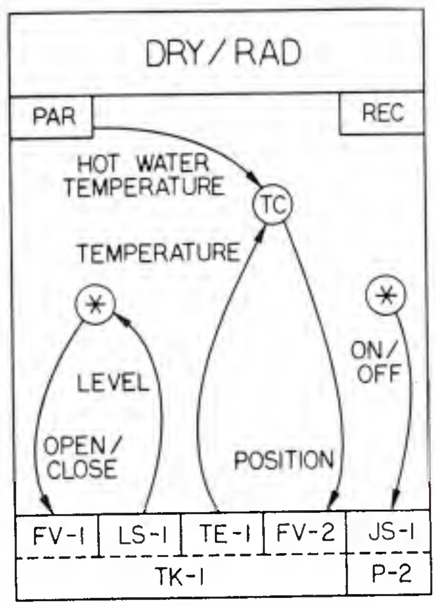
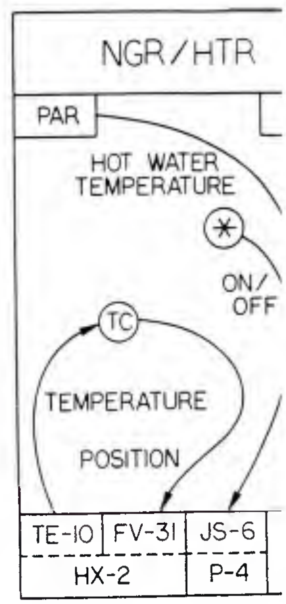
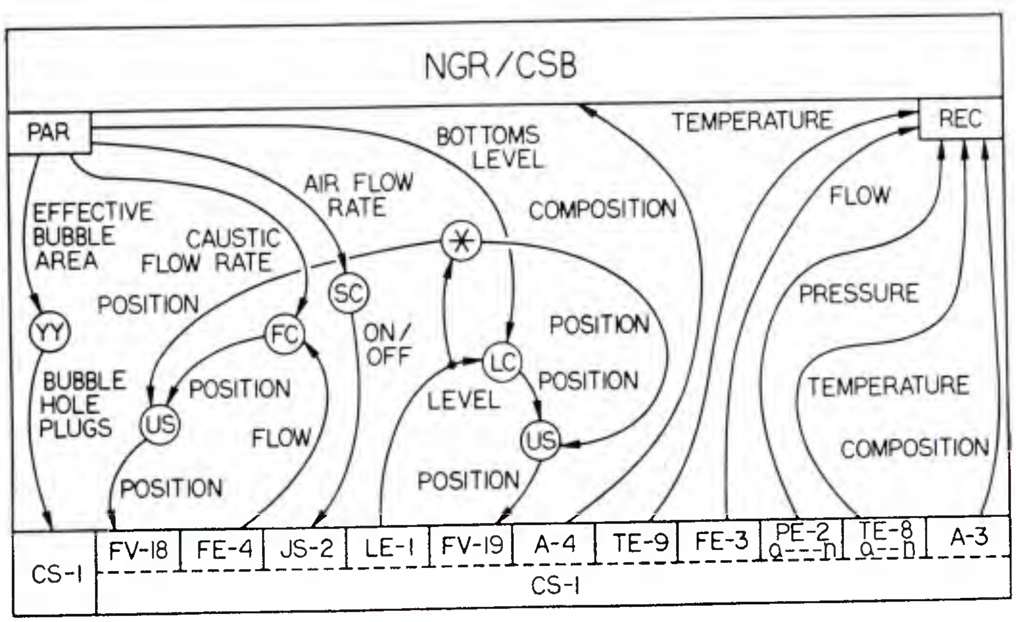
Figure 5. Event correlation diagram, modernized forced air dry (processes)

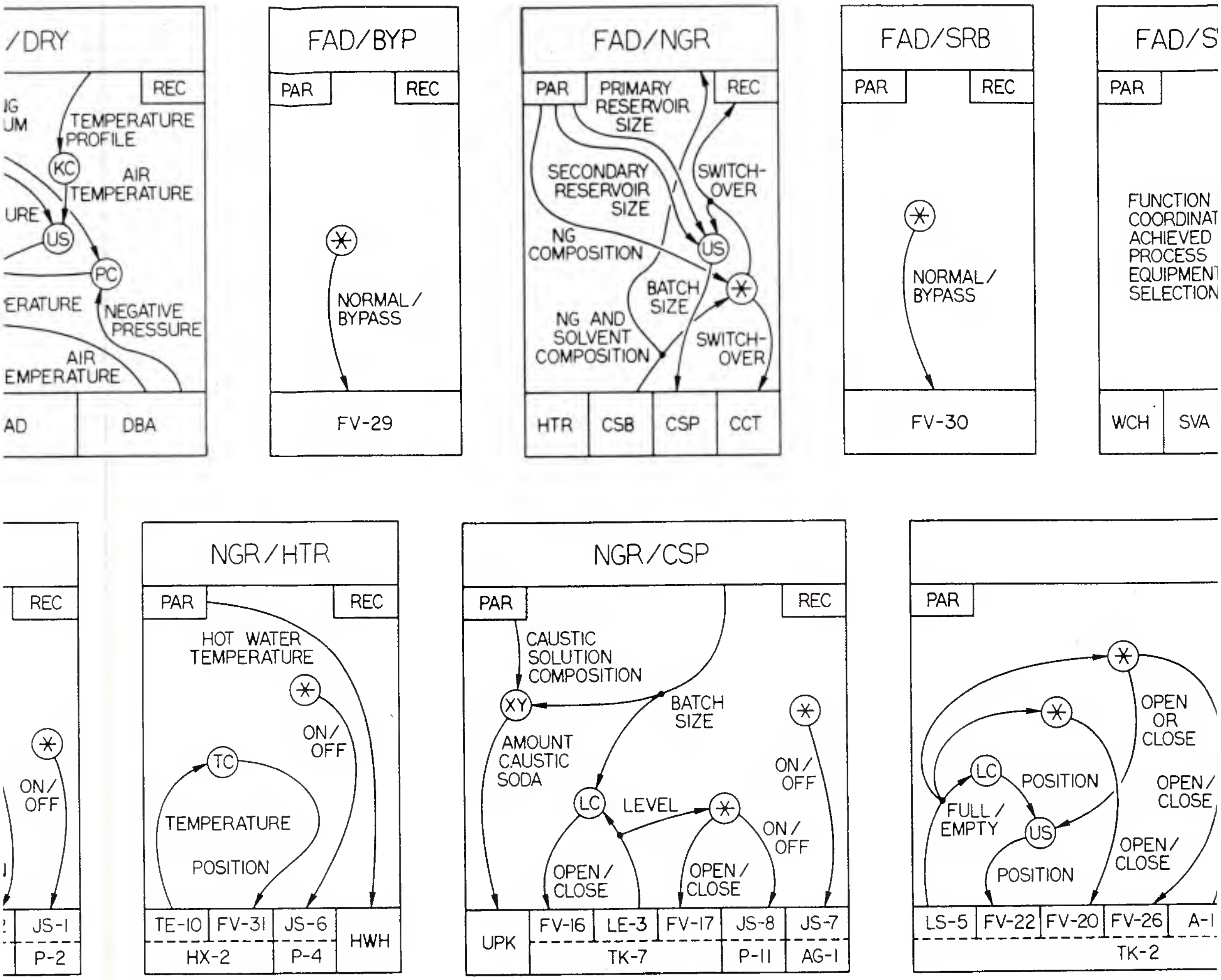
b

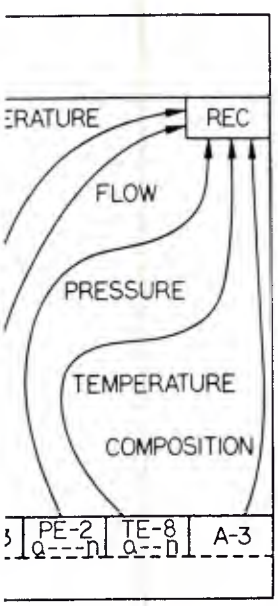


air dry (processes)

C


OPERATIONS MANAGEMENT / FAD
PAR
REC
SOLVENT COMPOSITION
PROPELLANT TYPE
1
2
n
NG COMPOSITION
SHUTDOWN
TEMPERATURE PROFILES
US
BYPASS
NG AND SOLVENT COMPOSITION
TEMPERATURE PROFILE
DRY
BYP
NGR
SRB
SVR

FAD/DRY
PAR
REC
BAY OPERATING VACUUM
TEMPERATURE PROFILE
AIR FLOW RATE
US
KC
PURGE AIR TEMPERATURE
AIR TEMPERATURE
AIR FLOW RATE
US
PC
AIR FLOW RATE
AIR TEMPERATURE
TC
NEGATIVE PRESSURE
DAMPER POSITION
AIR TEMPERATURE
CNV
RAD
DBA

FAD
PAR

DRY / CNV
PAR
REC
DAMPER POSITION
AIR FLOW RATE
SC
AIR FLOW
OPEN / CLOSE
POWER
FV-5
FV-6
JC-1
FE-1
HX-1
P-1

DRY / RAD
PAR
REC
HOT WATER TEMPERATURE
TC
TEMPERATURE
LEVEL
ON / OFF
OPEN / CLOSE
POSITION
FV-1
LS-1
TE-1
FV-2
JS-1
TK-1
P-2

NGR / HTR
PAR
HOT WATER TEMPERATURE
ON / OFF
TC
TEMPERATURE
POSITION
TE-10
FV-31
JS-6
HX-2
P-4

NGR / CSB
PAR
REC
BOTTOMS LEVEL
TEMPERATURE
EFFECTIVE BUBBLE AREA
AIR FLOW RATE
COMPOSITION
FLOW
CAUSTIC FLOW RATE
POSITION
SC
YY
FC
ON / OFF
POSITION
PRESSURE
LC
POSITION
BUBBLE HOLE PLUGS
US
POSITION
LEVEL
TEMPERATURE
FLOW
US
COMPOSITION
POSITION
POSITION
CS-1
FV-18
FE-4
JS-2
LE-1
FV-19
A-4
TE-9
FE-3
PE-2 a---n
TE-8 a---n
A-3
CS-1





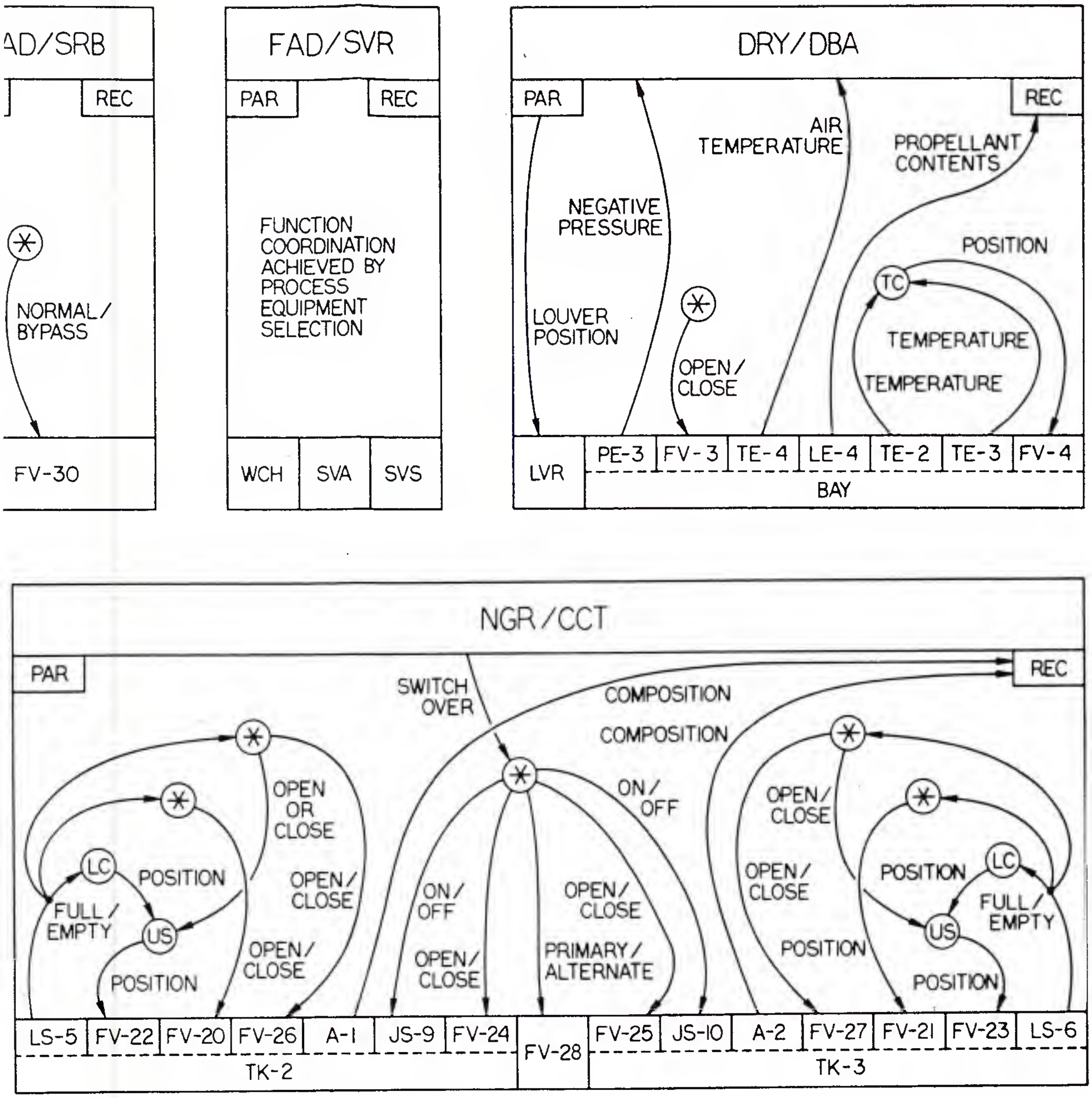
NOTES:-

1 - SYMBOLS: REF. ANSI Y32.20-1975 WITH USER'S CHOICE AS FOLLOWS
XY = "COMPOSITION" CALCULATION
YY = "SIEVE TRAY EFFECTIVE AREA" CALCULATION

2 - (*) = PROCEDURE CAUSED
REF. MODERNIZED FORCED AIR DRY EVENT CORRELATION DIAGRAM
PAR = ENGINEERING AND MANAGEMENT DATA PARAMETERS
REC = ENGINEERING AND MANAGEMENT DATA RECORDS

Figure 6. Control information-flow diagram, modernized forced air

(6)



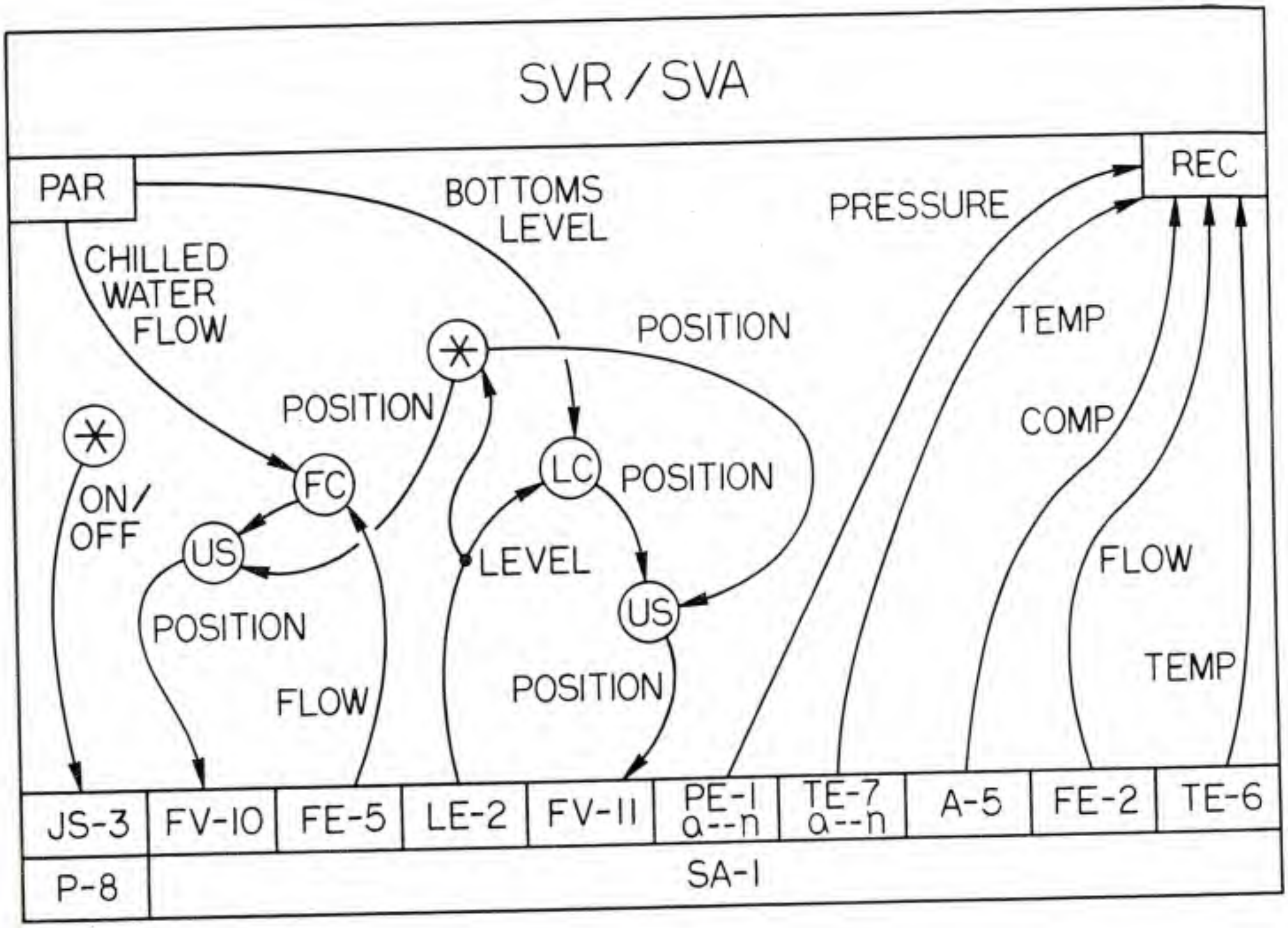
ER'S CHOICE

CALCULATION

RY EVENT

DATA PARAMETERS
DATA RECORDS

am, modernized forced air dry



SVR / SVA
PAR
REC
BOTTOMS LEVEL
PRESSURE
CHILLED WATER FLOW
TEMP
POSITION
POSITION
COMP
FC
LC
POSITION
ON/ OFF
US
LEVEL
FLOW
US
POSITION
TEMP
POSITION
FLOW
JS-3
FV-10
FE-5
LE-2
FV-11
PE-1 a--n
TE-7 a--n
A-5
FE-2
TE-6
P-8
SA-1

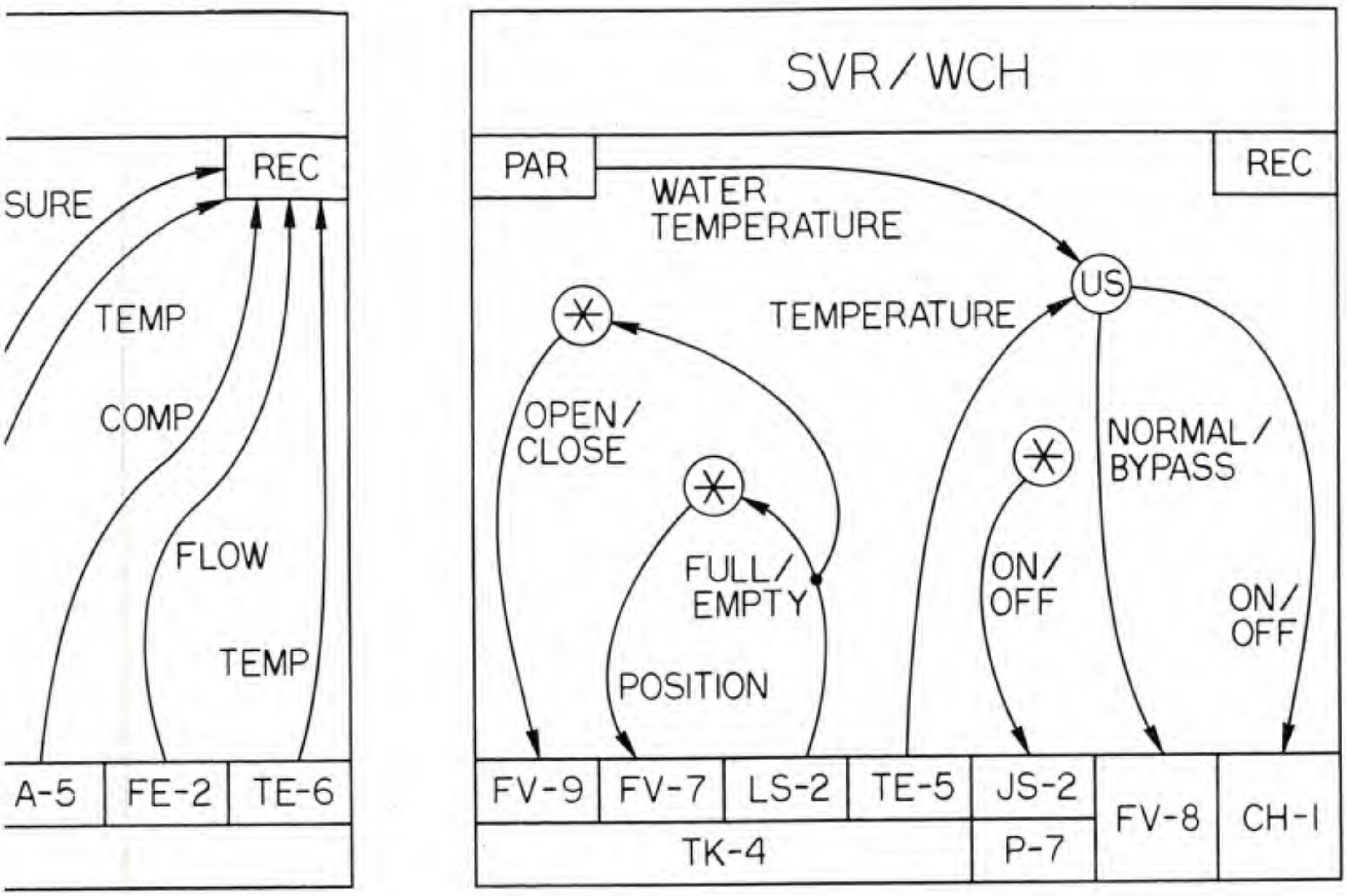
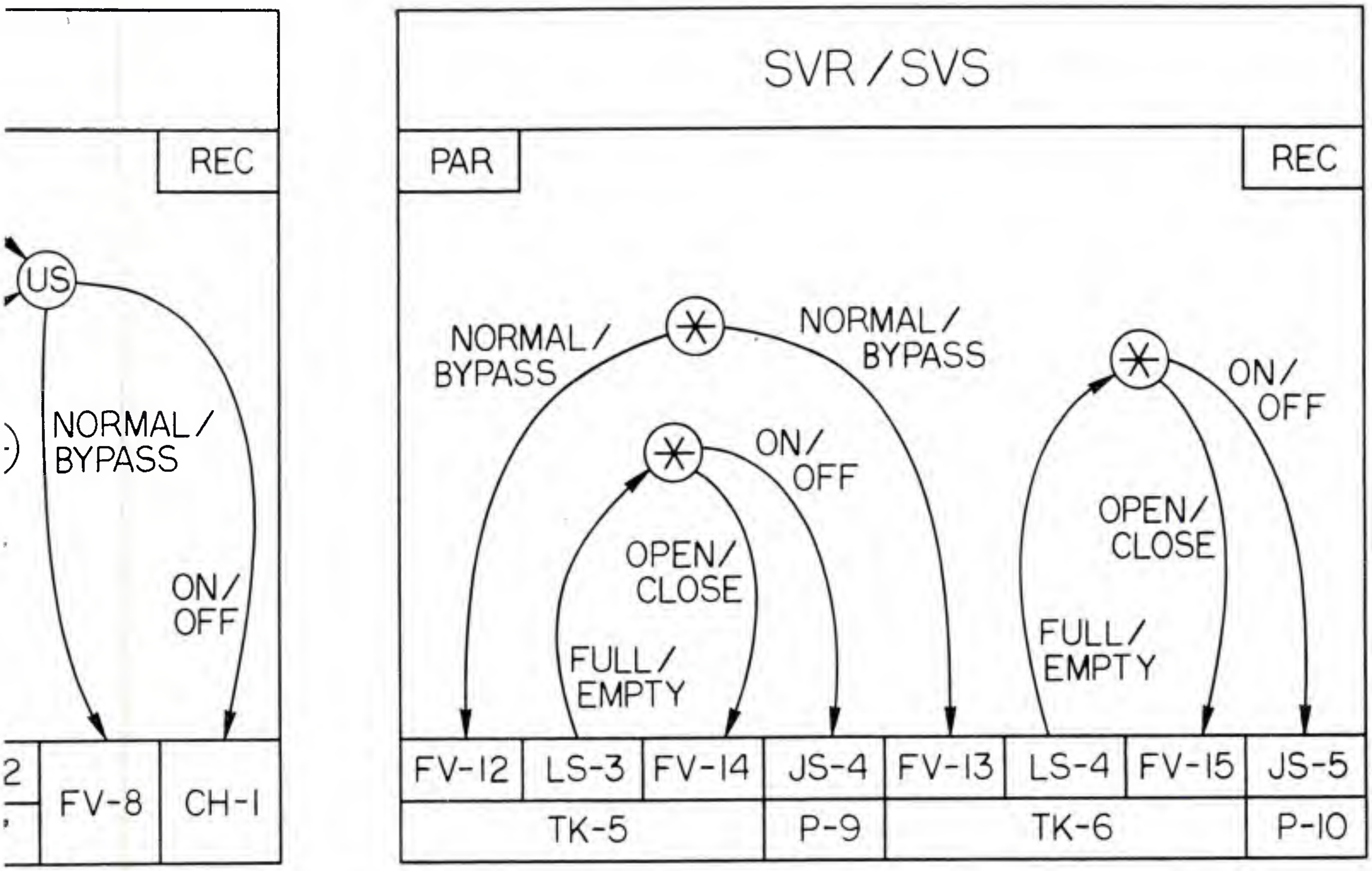


Figure 7. Control information-flow diagram, modernized forced air dr

(B)



, modernized forced air dry

APPENDIX
OPERATIONAL ANALYSIS SUPPLEMENT

CONTENTS

FIGURES

I. COORDINATION LABELING SCHEME

The coordination labeling scheme used on all Control Coordination Drawings, figures A6 to A20 is as follows. Upper case letters are used to represent each stream property for which coordination is to be identified. The kind of coordination of that variable is then indicated by the use of certain special symbols attached to the letter. All coordinations which have significance for the Control System Functional Criteria document are identified here with their corresponding statements of interpretation.

There are four coordination circumstances for which coordination labeling is defined: input flow, output flow, input stream characteristics, and output stream characteristics.

The list below summarizes the abbreviations used for the various stream characteristics on the Control Coordination Drawings.

	Characteristic Abbreviations
F	flow
X	composition
T	temperature
P	pressure

INPUT/OUTPUT FLOW COORDINATION

Flows establish the material connections between blocks, and are, therefore, treated in more detail than other characteristics of a stream. The symbol used for flow is F and the notation used to identify a block's expectation or regulation of stream flow is summarized below.

Input

F	no expectation on the arrival of material (any rate is acceptable)
F'	only one value of arrival rate is acceptable to the block
F"	a range of values of arrival rate is acceptable to the block
[F]	either the block implicitly determines this flow as a result of its explicit regulation activities on some other flow or characteristic or the structure of the block requires this flow as a result of some output
<F>	the block explicitly regulates the flow from this source

Output

F	no control over material withdrawal
F'	(not used; no meaning assigned to this symbol)
F"	a range of delivery rates may be established by the block
[F]	either the block implicitly determines this flow as a result of its explicit regulation activities on some other flow or characteristic or the structure of the block requires this flow

as a result of some output

<F> the block explicitly regulates the flow to this destination

INPUT/OUTPUT STREAM CHARACTERISTICS

Chemical Characteristics

When material connections are established between blocks, the values of other stream characteristics must then also be regarded compatibly by the two blocks. For a characteristic with symbol C the notation used to identify a block's expectations of stream characteristic is summarized below.

Input

C	no expectation on the value of this characteristic
C'	only one value of this characteristic is acceptable to the block
C"	a range of values of this characteristic is acceptable to the block
[C]	(not used; no meaning assigned to this symbol)
<C>	(not used; no meaning assigned to this symbol)

Output

C	no control over this characteristic
C'	(not used; no meaning assigned to this symbol)
C"	a range of values of this characteristic may be established by the block
[C]	either the block passes through an input flow characteristic or the block implicitly determines this characteristic as a result of its explicit regulation activities on some other characteristic
<C>	the block explicitly regulates the characteristic

Physical Characteristics

The physical nature of stream materials is called the stream type. There are several possible stream types, based on the liquid, solid, or gaseous nature of the material. These are summarized below.

Homogeneous

L	liquid
S	solid
G	gas
P	piece or unit

Heterogeneous

L,S	slurry
S,G	dust
G,L	vapor

II. INTRODUCTION TO BLOCK DESCRIPTIONS

The operational strategy for the Forced Air Dry described in the following block description analyses does not specify all process operations in a rigorous step-by-step operating procedure, but it does consider all steps which must be required for operation and exercise them to determine the data and task needs to be supplied by the final control system. Ultimate test and production strategies involve precise high-level coordinations and decisions. The derived control system must be able to support these activities, although not all decision and timing strategies have been defined by process operation design as yet.

III. BLOCK DESCRIPTION GUIDE

The contents of the Block Description are organized in outline structure and are written in the order in which they occur. To provide a guide to this discussion, the main headings in the Block Description are shown below.

I. Interfaces

- A. Directives
- B. Reports
- C. Information
- D. Coordination

II. Transfer Relations

- A. Directives / Operations
- B. Inputs / Operations / Outputs
- C. Free Boundaries

III. Decomposition of Block

- A. Subblock
- B. . . .

IV. Integration of Subblocks

- A. Strategy for directed action
- B. . . .

This document describes the intent and information content of each of the above-listed headings and explains the format of entries used to convey this information.

I. Interfaces

The Interface section specifies the information and material boundaries of the block.

A. Directives

Entries here define the directives which must be acted upon by this block. All blocks have at least two such entries, called NORMAL and OFF. Some of the more complex blocks have additional entries, such as IDLE and CYCLE. In nearly all cases, there are certain parameters that are needed to fully define the directive. These are entered as subentries below the directive. The intent here is to establish the existence of that information which must be provided in order for the block to perform its function. Actual values of such parameters are design dependent, but an entry here shows that such a value is needed.

B. Reports

Entries here define the reports which must be furnished by this block. All blocks have at least a Status entry, and many also have a Characteristics entry.

1. In most sequences of operation, successive events are predicated on the successful completion of previous events. Hence, every block supplies at least one indication of status to its supervising block as a statement of its current mode of operation.

2. The elements of Characteristics reports are values of internal process

variables which the supervising block needs for coordinating this block with other blocks or else for reporting to the supervising block.

C. Information

Many parameters of block operation constitute standard engineering or management data. In addition, a large fraction of operations data is not needed as much for direct control purposes as for plant operations analysis for adjusting engineering parameters.

1. Records of process data are made in the highest level block where such data has to be available for actual control purposes.

2. Parameters are retrieved by the highest level block in which they must be used to generate meaningful directives to lower level blocks.

D. Coordination

The entries in this section are included by reference to provide the following information: compatibility of coordination with other blocks and definition of coordination expectations of this block. Although not referenced directly in this section, the Functional Decomposition and Functional Consolidation diagrams, figures A-1 through A-4, may assist in following the material transfers between blocks.

II. Transfer Relations

The Transfer Relations section describes the connections between directed ac-

tions, stream flows, and processing operations from an external view of the block. There is no "explanation" of how these correlations of activities and properties are made, only a cataloging of them. In effect, they summarize the net result of all internal operations of the block in response to directives given to it. They are the correlations that are relevant to the way this block is used by its supervisor block.

A. Directives/Operations

Entries in the Directives/Operations section indicate that certain operations of the block are activated or deactivated by the receipt of various directives. A simple notation has been used to show these implications. Directives are written here as

directive ("operation"; "parameters")

where "operation" is the name of one of the directives in subsection I.A (Interfaces, Directives) and "parameters" is the list of relevant parameters which must be specified in order for the desired operation to be properly performed. The implication statement is written as

directive ("operation"; "parameters") => TRANSITION and STATE

to describe the transition of the process from one operational state to another and the maintenance of the new operational state. It is these transitions and states that are associated with flow and other characteristics of the streams to and from the block.

B. Inputs / Operations / Outputs

Entries in the Inputs/Operations/Outputs section relate the operation of states in the block and transitions between them to the characteristics of the input and output streams which they determine.

1. Input stream references are written in the form

flow of I:n, or characteristic of I:n

where n is the number of the identified input stream in the Operational Analysis drawings, figures A-5 through A-20.

2. Output stream references are written in the form

flow of O:n, or characteristic of O:n

where n is the number of the identified output stream in the Operational Analysis drawings, figures A-5 through A-20.

3. The format of entries in this subsection lists causes of an effect together with "and" or "or" as appropriate and then identifies the effect by a right arrow. In the case where a particular combination of causes gives rise to multiple effects, then all such effects are listed after the arrow. Causes are either (a) the operation of identified states or transition or (b) the flows or fixed characteristics of streams under block control.

C. Free Boundaries

Entries in the Free Boundaries section relate the effects of those characteristics of input and output streams over which the block has no control. Changes in these characteristics can alter both function behavior as well as other stream characteristics. The form of entries here is like that for those in subsection II.B (Transfer Relations, Inputs/Operations/Outputs).

III. Decomposition of Block

The Decomposition section identifies all of the subblocks which this block uses to carry out its activities. Each subblock is specified by its mnemonic and its meaning. Generally, subblock names are chosen to reflect the purpose the subblock serves as a part of the current block's operation. Then, for every subblock, its functional objective is listed, the directives and reports are summarized, and any quality characteristics of the product for which this subblock is responsible are identified. The format for these entries is

A. MNEMONIC - meaning of mnemonic showing purpose

1. objectives: statement of activity provided by this subblock
2. quality characteristics (product): characteristics which this subblock effects

In item 2, "product" is that intermediate or final plant product with which the activities in this block are concerned.

IV. Integration of Subblocks

The information in the Integration of Subblocks section forms the heart of the Block Description, for it is here that all sequencing, deciding, and monitoring functions of the block are used to interpret directives from the supervisor block and data from the subblocks and generate subblock tasks which accomplish the specified block operations. The entries here are organized according to the various directive actions called out in section II.B (Transfer Relations, Inputs/Operations/Outputs). Following each such directive is the set of control activities to be performed by the block in order to meet the directive.

A. Tasks which are issued to subblocks are written as

task ["SBN" : "operation" ; "parameters"]

where "SBN" is the subblock mnemonic to which the task is directed, "operation" is one of the directive headings in that subblock, and "parameters" are any information that the subblock needs in order to carry out the specified task. For those special cases when a parameter value must be something specific, the task is written as

task ["SBN" : "operation" ; "parameter = value"]

An example of such a case is when an operation is being idled but not shutdown, so that "production rate = 0%" is a known specific statement.

B. Queries by this block to a subblock to obtain information are written as

query ["SBN" : "type" ; "parameters"]

where "SBN" is again the menmonic of the subblock to which the query is directed, "type" is either Status or Characteristics, depending on what information is needed, and "parameters" identify the specific item(s) to be furnished. A common occurrence in setting up strategy is to verify that a specific condition in a subblock has been achieved, such as in "shutdown" to know when the block is empty. In this case, the query is used to ask if that specific condition is true. That query is written

query ["SBN" : "type" ; "parameter = value"]

where "value" is the specific condition for which a response is awaited.

C. Various groups of task/query statements constitute activities that have usual process operation names like "startup," "idle," "normal," and "shutdown." These labels are inserted between such groups to help explain the significance of that particular group. The labels are written as

ACTIVITY

so that they are easily referenced.

D. Generally, the strategies documented in this section consist of tasks and queries to subblocks which result from receiving directives from the supervising block, reporting data to the supervising block, and getting parameters from or putting records into the engineering/management database. The collec-

tion of steps are listed sequentially, but this does not always mean that the sequence is specifically correct. Rather, the important thing to be documented here is all of the monitoring, deciding, and tasking that are to be carried out by the block. By arranging these activities in a reasonable, sequential order, no activity should be overlooked. As illustrated by the directive entries in section I.A (Interfaces, Directives), specific process values or specific process sequences are not as important (and are not known during criteria generation) as the variables or activities that must be provided for at this point in the design of the plant.

IV. BLOCK DESCRIPTIONS

The Block Descriptions for Forced Air Dry are organized as shown in the following index outline. Indentation is used to show that the indented block is directed by, and reports to, the block above and to the left of it. For each block, the three-letter block name abbreviation used on all operational coordination drawings and block descriptions is given first, followed by its explanatory operational name.

- FAD: Forced Air Dry
  - DRY: Dry
    - CNV: Convective Heat
    - RAD: Radiant Heat
    - DBA: Drying Bay Area
  - BYP: Pollution Abatement Bypass
  - NGR: Nitroglycerin Removal
    - HTR: Heater
    - CSB: Caustic Scrub
    - CCT: Caustic Circulate
    - CSP: Caustic Solution Preparation
  - SRB: Solvent Removal Bypass
  - SVR: Solvent Removal
    - SVA: Solvent Absorption
    - SVS: Solvent Storage
    - WCH: Water Chiller

Block Designation: FAD - Forced Air Dry
Form 80311

Revision: 1 Date: Nov 1980 ARRADCOM - TSD - PROC CON SYS SEC

I. Interfaces

A. Directives

1. LOAD
2. CYCLE
   a. propellant type
3. UNLOAD
4. OFF

B. Reports

1. status
   a. operation mode (startup, load, initiate, cycle, suspend, unload, resume, shut-down, off)
   b. contents (empty, full)
2. characteristics
   a. none

C. Information

1. records
   a. none
2. parameters
   a. air temperature profiles (as a function of time) for each propellant type

D. Coordination

1. see Process Description Section III, FAD System Functional Criteria
2. see Level 0 Control Coordination Drawing, External, figure A-5

II. Transfer Relations

A. Directives / Operations

1. directive (LOAD) => transition from OFF to LOAD (STARTUP) and maintain LOAD
2. directive (CYCLE) => transition from LOAD to CYCLE (INITIATE) and maintain CYCLE
3. directive (UNLOAD) => transition from CYCLE to UNLOAD (SUSPEND) and maintain UNLOAD
4. directive (LOAD) => transition from UNLOAD to LOAD (RESUME) and maintain LOAD
5. directive (OFF) => transition from HOLD to OFF (SHUTDOWN)

B. Inputs / Operations / Outputs

1. STARTUP => flow of I:2 and flow of O:2
2. flow of I:1 and LOAD => increasing propellant contents
3. LOAD => flow of I:2 and flow of O:2
4. composition of I:1 and NORMAL => flow and composition of I:2, O:2, O:3, O:4, O:5
5. flow of O:2 and UNLOAD => decreasing propellant contents
6. UNLOAD => flow of I:2 and flow of O:2
7. RESUME => flow of I:2 and flow of O:2

Block Designation: FAD - Forced Air Dry
Form 80311

C. Free Boundaries

1. none

III. Decomposition of Block

A. DRY - Dry

1. objectives: remove solvents from green propellant with hot air stream
2. quality characteristics: composition of dry propellant (solvents content)

B. BYP - Pollution Abatement Bypass

1. objectives: direct air:gas exhaust from DRY to avoid unnecessary pollution abatement processing
2. quality characteristics: none

C. NGR - Nitroglycerine Removal

1. objectives: remove nitroglycerine from air:gas stream
2. quality characteristics: composition of air:gas stream (hycrocarbon content)

D. SRB - Solvent Recovery Bypass

1. objectives: direct air:gas stream from NGR to avoid unnecessary solvent recovery processing
2. quality characteristics: none

E. SVR - Solvent Removal

1. objectives: remove solvents from air:gas stream
2. quality characteristics: composition of air:gas stream (solvents content)

IV. Integration - see Level 0 Control Coordination Drawing, Internal, figure A-5

A. directive (LOAD) => STARTUP and LOAD

STARTUP

1. prepare dry, nitroglycerin removal, and solvent removal areas
   a. task [DRY: IDLE]
   b. task [NGR: IDLE]
   c. task [SVR: IDLE]
2. establish air flow and clean operations
   a. task [BYP: NORMAL]
   b. task [NGR: NORMAL]
   c. task [SRB: NORMAL]
   d. task [SVR: NORMAL]

LOAD

3. report (status; mode=load)
4. report (status; contents=empty/full)
   a. query [DRY: status; contents=empty/full]

B. directive (CYCLE) => INITIATION and CYCLE

INITIATION

1. establish drying conditions
   a. select parameter (temperature profile) based on the directive (propellant type)
   b. task [DRY: NORMAL; selected temperature profile]

CYCLE

2. report (status; mode=cycle)

C. directive (UNLOAD) => SUSPEND and UNLOAD

SUSPEND

1. open drying area
   a. task [DRY: IDLE]
   b. task [NGR: OFF]
   c. task [SVR: HOLD]
   d. task [BYP: BYPASS]
   e. task [SRB: BYPASS]

UNLOAD

2. report (status; mode=unload)
3. report (status; contents=empty/full)
   a. query [DRY: status; contents=empty/full]

D. directive (LOAD) => RESUME and LOAD

RESUME

1. prepare nitroglycerine removal and solvent removal areas to continue
   a. task [NGR: IDLE]
   b. task [SVR: IDLE]
2. reestablish air flow and clean operations
   a. task [BYP: NORMAL]
   b. task [NGR: NORMAL]
   c. task [SRB: NORMAL]
   d. task [SVR: NORMAL]

LOAD

3. report (status; mode=load)
4. report (status; contents=empty/full)
   a. query [DRY: status; contents=empty/full]

E. directive (OFF) => SHUTDOWN and OFF

SHUTDOWN

1. terminate dry operation
   a. task [DRY: OFF]

2. empty solvent removal area
   a. task [SVR: OFF]

OFF

3. report (status; mode=off)

Block Designation: DRY - Dry
Form 80311

Revision: 1 Date: Nov 1980 ARRADCOM - TSD - PROC CON SYS SEC

I. Interfaces

A. Directives

1. NORMAL
   a. air temperature profile
2. IDLE
3. OFF

B. Reports

1. status
   a. operation mode (startup, idle, initiate, normal, suspend, shutdown, off)
2. characteristics
   a. none

C. Information

1. records
   a. none
2. parameters
   a. purge air temperature
   b. air flow rate
   c. bay operating vacuum

D. Coordination

1. see Level 0 Control Coordination Drawing, Internal, figure A-5
2. see Level 1 Control Coordination Drawing, External, figure A-6

II. Transfer Relations

A. Directives / Operations

1. directive (IDLE) => transition from OFF to IDLE (STARTUP) and maintain IDLE
2. directive (NORMAL) => transition from IDLE to NORMAL (INITIATE) and maintain NORMAL
3. directive (IDLE) => transition from NORMAL to IDLE (SUSPEND) and maintain IDLE
4. directive (OFF) => transition from IDLE to OFF(SHUTDOWN)

B. Inputs / Operations / Outputs

1. STARTUP => flow of I:2 and flow and temperature of O:1
2. flow of I:1 and IDLE => increasing propellant contents
3. NORMAL => flow of I:2 and flow and temperature of O:1
4. composition of I:1 and NORMAL => composition of O:1 and O:2
5. flow of O:2 and IDLE => decreasing propellant contents

C. Free Boundaries

1. none

Block Designation: DRY - Dry
Form 80311

III. Decomposition of Block

A. CNV - Convective Heat

1. objectives: supply heated air to DBA
2. quality characteristics: temperature and flow rate of heated air

B. RAD - Radiant Heat

1. objectives: supply hot water to DBA
2. quality characteristics: temperature and flow of hot water

C. DBA - Drying Bay Area

1. objectives: heat green propellant and evaporate solvents into air stream
2. quality characteristics: composition of dry propellant, composition of air stream

IV. Integration - see Level 1 Control Coordination Drawing, Internal, figure A-6

A. directive (IDLE) => STARTUP and IDLE

STARTUP

1. enable loading
   a. task [CNV: NORMAL; air flow rate] to meet (air flow rate = parameter (air flow rate))
   b. query [DBA: characteristics; air temperature]
   c. task [CNV: NORMAL; damper position] to meet (air temperature = parameter (purge air temperature))
   d. task [DBA: OPEN]
   e. task [RAD: IDLE]

IDLE

2. report (status; mode=idle)

B. directive (NORMAL) => INITIATION and NORMAL

INITIATION

1. establish drying area conditions
   a. task [RAD: NORMAL]
   b. task [DBA: CLOSED]

NORMAL

2. report (status; mode=normal)
3. count elapsed time
4. coordinate air flow
   a. query [DBA: characteristics; negative pressure]
   b. task [CNV: NORMAL; air flow rate] to meet (negative pressure = parameter (bay operating vacuum))
5. establish air temperature profile

Block Designation: DRY - Dry
Form 80311

a. query [DBA: characteristics; air temperature]
b. task [CNV: NORMAL; damper position] to meet (air temperature = directive (air temperature profile(elapsed time)))

C. directive (IDLE) => SUSPEND and IDLE

SUSPEND

1. enable unloading/loading
   a. task [RAD: IDLE]
   b. task [DBA: OPEN]
   c. query [DBA: characteristics; air temperature]
   d. task [CNV: NORMAL; damper position] to meet (air temperature = parameter (purge air temperature))
   e. task [CNV: NORMAL; air flow rate] to meet (air flow rate = parameter (air flow rate))

IDLE

2. report (status; mode=idle)

D. directive (OFF) => SHUTDOWN and OFF

SHUTDOWN

1. terminate operations
   a. task [RAD: OFF]
   b. task [CNV: OFF]
   c. query [RAD: status; mode=off] and query [CNV: status; mode=off]
   d. task [DBA: CLOSED]

OFF

2. report (status; mode=off)

Block Designation: CNV - Convective Heat
Form 80311

Revision: 1 Date: Nov 1980 ARRADCOM - TSD - PROC CON SYS SEC

I. Interfaces

A. Directives

1. NORMAL
   a. damper position
   b. air flow rate
2. OFF

B. Reports

1. status
   a. operation mode (startup, normal, shutdown, off)
2. characteristics
   a. none

C. Information

1. records
   a. none
2. parameters
   a. none

D. Coordination

1. see Level 1 Control Coordination Drawing, Internal, figure A-6
2. see Level 2 Control Coordination Drawing, External, figure A-7

II. Transfer Relations

A. Directives / Operations

1. directive (NORMAL) => transition from OFF to NORMAL (STARTUP) and maintain NOR-MAL
2. directive (OFF) => transition from NORMAL to OFF (SHUTDOWN)

B. Inputs / Operations / Outputs

1. NORMAL => flow of I:1 and flow and temperature of O:2
2. flow of O:2 => flow of I:2
3. flow of I:1 => flow of O:1

C. Free Boundaries

a. none

III. Decomposition of Block

A. HX-1 - Air Heater

1. objectives: transfer heat from steam into the air stream
2. quality characteristics: temperature of air stream

B. P-1 - Hot Air Blower

1. objectives: transfer air through air heater to drying bay
2. quality characteristics: flow of air stream

C. FE-1 - Air Flow Rate Element

1. objectives: monitor air flow rate
2. quality characteristics: none

D. JC-1 - Blower Power Control

1. objectives: throttle blower power
2. quality characteristics: flow of air stream

E. FV-5 - Steam Flow Valve

1. objectives: throttle steam flow to hot air heater
2. quality characteristics: none

F. FV-6 - Air Mixing Damper

1. objectives: throttle mixing of heated and unheated air
2. quality characteristics: temperature of air stream

IV. Integration - see Level 2 Control Coordination Drawing, Internal, figure A-7

A. directive (NORMAL) => STARTUP and NORMAL

STARTUP

1. start hot air stream
   a. task [FV-5: open]
   b. query [FE-1: flow]
   c. task [JC-1: power] to meet (flow = directive(air flow rate))

NORMAL

2. report (status; mode=normal)
3. adjust air mixture
   a. task [FV-6: position=directive(damper position)]

B. directive (OFF) => SHUTDOWN and OFF

SHUTDOWN

1. stop hot air stream
   a. task [FV-5: closed]
   b. task [JC-1: power=off]
   c. task [FV-6: position=bypass]

OFF

2. report (status; mode=off)

Block Designation: RAD - Radiant Heat
Form 80311

Revision: 1 Date: Nov 1980 ARRADCOM - TSD - PROC CON SYS SEC

I. Interfaces

A. Directives

1. NORMAL
2. IDLE
3. OFF

B. Reports

1. status
   a. operation mode (start, idle, initiate, normal, suspend, shutdown, off)
2. characteristics
   a. none

C. Information

1. records
   a. none
2. parameters
   a. hot water temperature

D. Coordination

1. see Level 1 Control Coordination Drawing, Internal, figure A-6
2. see Level 2 Control Coordination Drawing, External, figure A-8

II. Transfer Relations

A. Directives / Operations

1. directive (IDLE) => transition from OFF to IDLE (STARTUP) and maintain IDLE
2. directive (NORMAL) => transition from IDLE to NORMAL (INITIATE) and maintain NORMAL
3. directive (IDLE) => transition from NORMAL to IDLE (SUSPEND) and maintain IDLE
4. directive (OFF) => transition from IDLE to OFF (SHUTDOWN)

B. Inputs / Operations / Outputs

1. STARTUP => flow of I:2
2. flow of I:2 => increasing contents
3. IDLE => flow of I:1
4. flow of I:1 => flow of O:2 and temperature of O:1
5. NORMAL => flow of I:1 and flow of O:1
6. flow of O:1 => decreasing contents

C. Free Boundaries

1. flow of I:3 => increasing contents
2. composition of I:2 => composition of O:1

III. Decomposition of Block

Block Designation: RAD - Radiant Heat
Form 80311

A. TK-1 - Hot Water Tank

1. objectives: transfer heat from steam to water:glycol
2. quality characteristics: temperature of water:glycol

B. P-2 - Hot Water Pump

1. objectives: transfer hot water from hot water tank to bay
2. quality characteristics: none

C. LS-1 - Hot Water Tank Level Switch

1. objectives: monitor water:glycol level in hot water tank
2. quality characteristics: none

D. TE-1 - Hot Water Temperature Element

1. objectives: monitor water:glycol temperature in hot water tank
2. quality characteristics: none

E. JS-1 - Hot Water Pump Power Switch

1. objectives: start/stop hot water pump
2. quality characteristics: none

F. FV-1 - Water:Glycol Fill Valve

1. objectives: throttle filling of hot water tank with water:glycol
2. quality characteristics: none

G. FV-2 - Steam Flow Valve

1. objectives: throttle flow of steam to hot water tank
2. quality characteristics: temperature of hot water:glycol

IV. Integration - see Level 2 Control Coordination Drawing, Internal, figure A-8

A. directive (IDLE) => STARTUP and IDLE

STARTUP

1. fill block
   a. task [FV-1: open]
   b. query [LS-1: level=full], then task [FV-1: closed]
2. heat the contents
   a. query [TE-1: temperature]
   b. task [FV-2: position] to meet parameter(hot water temperature)

IDLE

3. report (status; mode=idle)

B. directive (NORMAL) => INITIATE and NORMAL

Block Designation: RAD - Radiant Heat
Form 80311

INITIATE

1. start circulation
   a. task [JS-1: on]

NORMAL

2. report (status; mode=normal)

C. directive (IDLE) => SUSPEND and IDLE

SUSPEND

1. stop circulation
   a. task [JS-1: off]

IDLE

2. report (status; mode=idle)

D. directive (OFF) => SHUTDOWN and OFF

SHUTDOWN

1. stop heating
   a. task [FV-2: closed]

OFF

2. report (status; mode=off)

Block Designation: DBA - Drying Bay Area
Form 80311

Revision: 1 Date: Nov 1980 ARRADCOM - TSD - PROC CON SYS SEC

I. Interfaces

A. Directives

1. OPEN
2. CLOSED

B. Reports

1. status
   a. operation mode (open, closed)
2. characteristics
   a. air temperature
   b. negative pressure

C. Information

1. records
   a. propellant contents
2. parameters
   a. louver position

D. Coordination

1. see Level 1 Control Coordination Drawing, Internal, figure A-6
2. see Level 2 Control Coordination Drawing, External, figure A-9

II. Transfer Relations

A. Directives / Operations

1. directive (OPEN) => transition from CLOSED to OPEN and maintain OPEN
2. directive (CLOSED) => transition from OPEN to CLOSED and maintain CLOSED

B. Inputs / Operations / Outputs

1. none

C. Free Boundaries

1. flow of I:2 => increasing propellant contents
2. flow of O:1 => decreasing propellant contents
3. flow of I:3 => flow of O:2
4. flow, temperature, and composition of I:1 and composition and amount of I:2 => flow, temperature, and composition of O:3 and composition and amount of O:1

III. Decomposition of Block

A. BAY-1 - Drying Bay

1. objectives: enable transfer of solvents from propellant to air
2. quality characteristics: none

B. LVR - Air Louvers

1. objectives: distribution of hot air flow
2. quality characteristics: uniformity of propellant drying

C. FV-3 - Drying Bay Doors

1. objectives: throttle loading and unloading of propellant
2. quality characteristics: none

D. FV-4 - Radiator Loop Balance Valve

1. objectives: throttle relative flow between two radiator loops
2. quality characteristics: uniformity of propellant drying

E. LE-4 - Bay Contents Level Element

1. objectives: monitor amount of propellant in BAY-1
2. quality characteristics: none

F. TE-2 - Hot Water Return Temperature Element, Loop.1

1. objectives: monitor temperature of water return from loop.1
2. quality characteristics: uniformity of propellant drying

G. TE-3 - Hot Water Return Temperature Element, Loop.2

1. objectives: monitor temperature of water return from loop.2
2. quality characteristics: uniformity of propellant drying

H. TE-4 - Bay Air Exhaust Temperature Element

1. objectives: monitor temperature of exhaust air from bay
2. quality characteristics: none

I. PE-3 - Bay Negative Pressure Element

1. objectives: monitor negative pressure in bay
2. quality characteristics: safety

IV. Integration - see Level 2 Control Coordination Drawing, Internal, figure A-9

A. directive (OPEN) => OPEN

OPEN

1. set air distribution
   a. task [LVR: position=parameter(louver position)]
2. enable propellant transfer
   a. task [FV-3: open]
3. report (status; mode=open)
4. monitor propellant contents
   a. query [LE-4: contents]
   b. record (propellant contents)

Block Designation: DBA - Drying Bay Area
Form 80311

B. directive (CLOSED) => CLOSED

CLOSED

1. disable propellant transfer
   a. task [FV-3: closed]
2. balance hot water loops
   a. query [TE-2: temperature.1], query [TE-3: temperature.2]
   b. task [FV-4: position] to meet (temperature.1 - temperature.2 =0)
3. report (characteristic; air temperature)
   a. query [TE-4: temperature]
4. report (characteristics; negative pressure)
   a. query [PE-3: negative pressure]

Block Designation: BYP - Pollution Abatement Bypass
Form 80311

Revision: 1 DATE: Nov 80 ARRADCOM - TSD - PROC CON SYS SEC

I. Interfaces

A. Directives

1. NORMAL
2. BYPASS

B. Reports

1. status
   a. operation mode (bypass, normal)
2. characteristics
   a. none

C. Information

1. records
   a. none
2. parameters
   a. none

D. Coordination

1. see Level 0 Control Coordination Drawing, Internal, figure A-5
2. see Level 1 Control Coordination Drawing, External, figure A-10

II. Transfer Relations

A. Directives / Operations

1. directive (NORMAL) => transition from BYPASS to NORMAL and maintain NORMAL
2. directive (BYPASS) => transition from NORMAL to BYPASS and maintain BYPASS

B. Inputs / Operations / Outputs

1. NORMAL and flow, composition, and temperature of I:1 => flow, composition, and temperature of O:2
2. BYPASS and flow, composition, and temperature of I:1 => flow, composition, and temperature of O:1

C. Free Boundaries

a. none

III. Decomposition of Block

A. FV-29 - Bypass Valve

1. objectives: select air:gas stream output
2. quality characteristics: none

Block Designation: BYP - Pollution Abatement Bypass
Form 80311

IV. Integration - see Level 1 Control Coordination Drawing, Internal, figure A-10

A. directive (NORMAL) => NORMAL

NORMAL

1. select normal output
   a. task [FV-29: position to pollution abatement]

B. directive (BYPASS) => BYPASS

BYPASS

1. select bypass output
   a. task [FV-29: position to atmosphere]

Block Designation: NGR - Nitroglycerin Removal
Form 80311

Revision: 1 Date: Nov 1980 ARRADCOM - TSD - PROC CON SYS SEC

I. Interfaces

A. Directives

1. NORMAL
2. IDLE
3. OFF

B. Reports

1. status
   a. operation mode (startup, idle, initiate, normal, shutdown, off)
2. characteristics
   a. none

C. Information

1. records
   a. switchover
2. parameters
   a. primary reservoir size
   b. alternate reservoir size
   c. nitroglycerin composition specification

D. Coordination

1. see Level 0 Control Coordination Drawing, Internal, figure A-5
2. see Level 1 Control Coordination Drawing, External, figure A-11

II. Transfer Relations

A. Directives / Operations

1. directive (IDLE) => transition from OFF to IDLE (STARTUP) and maintain IDLE
2. directive (NORMAL) => transition from IDLE to NORMAL (INITIATION) and maintain NORMAL
2. directive (OFF) => transition from NORMAL to OFF (SHUTDOWN)

B. Inputs / Operations / Outputs

1. STARTUP => flow of I:2 and I:3
2. NORMAL => flow of I:1 and flow of O:2 and flow of I:3
3. composition and temperature of I:1 and NORMAL => composition and temperature of O:2 and composition of O:1
4. SHUTDOWN => flow of O:1

C. Free Boundaries

1. none

III. Decomposition of Block

Block Designation: NGR - Nitroglycerin Removal
Form 80311

A. HTR - Heater

1. objectives: supply hot water makeup to CCT and prevent nitroglycerin condensation
2. quality characteristics: hot water temperature

B. CSB - Caustic Scrub

1. objectives: enable reaction and absorption of nitroglycerine from air:gas stream to caustic water stream
2. quality characteristics: composition of air:gas stream (hydrocarbon content)

C. CCT - Caustic Circulate

1. objectives: supply caustic water stream to CSB
2. quality characteristics: none

D. CSP - Caustic Solution Preparation

1. objectives: supply caustic water to CCT
2. quality characteristics: composition of caustic water

IV. Integration - see Level 1 Control Coordination Drawing, Internal, figure A-11

A. directive (IDLE) => STARTUP and IDLE

STARTUP

1. determine batch size according to need
   a. if (switchover=false), then batch size = parameter (primary reservoir size)
   b. if (switchover=true), then batch size = parameter (primary reservoir size) + parameter (alternate reservoir size)
2. prepare caustic water solution
   a. task [CSP: BATCH; batch size]
3. transfer solution to circulation reservoirs
   a. task [CCT: PRIMARY NORMAL]
   b. task [CSP: OFF]
4. establish column flooding
   a. task [CSB: IDLE]
5. establish hot water makeup and nitroglycerin condensate prevention
   a. task [HTR: NORMAL]

IDLE

6. report (status; mode=idle)

B. directive (NORMAL) => INITIATION and NORMAL

INITIATION

1. establish air flow
   a. task [CSB: NORMAL]

NORMAL

2. report (status; mode=normal)
3. maintain effective caustic circulation
   a. query [CSB: characteristics; nitroglycerine composition at outlet]
   b. if (nitroglycerin composition at outlet) > parameter(nitroglycerin composition specification), then
   task [CCT: SECONDARY NORMAL]
   c. record (switchover)

C. directive (OFF) => SHUTDOWN and OFF

SHUTDOWN

1. terminate operation and empty block
   a. task [HTR: OFF]
   b. task [CSB: OFF]
   c. task [CCT: OFF]

OFF

2. report (status; mode=off)

Block Designation: HTR - Heater
Form 80311

Revision: 1 Date: Nov 1980 ARRADCOM - TSD - PROC CON SYS SEC

I. Interfaces

A. Directives

1. NORMAL
2. OFF

B. Reports

1. status
   a. operation mode (startup, normal, shutdown, off)
2. characteristics
   a. none

C. Information

1. records
   a. none
2. parameters
   a. hot water temperature
   b. duct wall temperature to remain above dew point for all nitroglycerin concentration levels

D. Coordination

1. see Level 1 Control Coordination Drawing, Internal, figure A-11
2. see Level 2 Control Coordination Drawing, External, figure A-12

II. Transfer Relations

A. Directives / Operations

1. directive (NORMAL) => transition from OFF to NORMAL (STARTUP) and maintain NORMAL
2. directive (OFF) => transition from NORMAL to OFF (SHUTDOWN)

B. Inputs / Operations / Outputs

1. NORMAL => temperature of O:1

C. Free Boundaries

1. flow and composition of I:1 => flow and composition of O:1
2. flow of O:2 => flow of I:2
3. composition of I:2 => composition of O:2

III. Decomposition of Block

A. HWH - Hot Water Heater

1. objectives: enable transfer of heat to water
2. quality characteristics: none

B. HX-2 - Duct Air Heater

1. objectives: prevent nitroglycerine condensation on duct surface
2. quality characteristics: temperature of air:gas stream

C. P-4 - Hot Water Pump

1. objectives: circulate hot water between hot water heater and duct air heater and supply hot water
2. quality characteristics: none

D. FV-31 - Hot Water Diverter Valve

1. objectives: divert hot water for duct heating
2. quality characteristics: none

E. JS-6 - Hot Water Pump Power Switch

1. objectives: start/stop hot water pump
2. quality characteristics: none

F. TE-10 - Duct Wall Temperature Element

1. objectives: monitor duct wall temperature
2. quality characteristics: none

IV. Integration - see Level 2 Control Coordination Drawing, Internal, figure A-12

A. directive (NORMAL) => STARTUP and NORMAL

STARTUP

1. heat and circulate contents
   a. task [HWH: on; parameter(hot water temperature)]
   b. task [JS-6: on]
2. maintain duct wall temperature
   a. query [TE-10: duct wall temperature]
   b. task [FV-31: position] to meet (wall temperature = parameter (duct wall temperature))

NORMAL

3. report (status; mode=normal)

B. directive (OFF) => SHUTDOWN and OFF

SHUTDOWN

1. stop operation
   a. task [HWH: off]
   b. task [JS-6: off]

OFF

Block Designation: HTR - Heater
Form 80311

2. report (status; mode=off)

Block Designation: CSB - Caustic Scrub
Form 80311

Revision: 1 Date: Nov 1980 ARRADCOM - TSD - PROC CON SYS SEC

I. Interfaces

A. Directives

1. NORMAL
2. IDLE
3. OFF

B. Reports

1. status
   a. operation mode (startup, idle, initiate, normal, shutdown, off)
2. characteristics
   a. nitroglycerin composition at outlet

C. Information

1. records
   a. pressure distribution profile
   b. temperature distribution profile
   c. caustic water temperature
   d. air flow rate
   e. composition of inlet air:gas
   f. composition of outlet air:gas
2. parameters
   a. bottoms level
   b. effective bubble area
   c. caustic water flow rate
   d. air flow rate

D. Coordination

1. see Level 1 Control Coordination Drawing, Internal, figure A-11
2. see Level 2 Control Coordination Drawing, External, figure A-13

II. Transfer Relations

A. Directives / Operations

1. directive (IDLE) => transition from OFF to IDLE (STARTUP) and maintain IDLE
2. directive (NORMAL) => transition from IDLE to NORMAL (INITIATION) and maintain NORMAL
3. directive (OFF) => transition from NORMAL to OFF (SHUTDOWN)

B. Inputs / Operations / Outputs

1. STARTUP => flow of I:2
2. IDLE or NORMAL => flow of I:2 and flow of O:2
3. flow of I:2 => increasing contents
4. flow of O:2 => decreasing contents
5. NORMAL => flow of O:1
6. flow of O:1 => flow of I:1

7. flow, composition, and temperature of I:1 and flow, composition, and temperature of I:2 => composition and temperature of O:1 and composition and temperature of O:2

C. Free Boundaries

1. flow of I:1 => flow of O:1

III. Decomposition of Block

A. CS-1 - Caustic Scrubber

1. objectives: bring air:gas stream into contact with caustic water stream
2. quality characteristics: composition of air:gas stream

B. P-3 - Air Exhaust Blower

1. objectives: transfer air:gas stream through CS-1
2. quality characteristics:

C. A-3 - Air:Gas Composition Analyzer

1. objectives: monitor composition of inlet air:gas stream
2. quality characteristics: none

D. A-4 - Air:Gas Composition Analyzer

1. objectives: monitor composition of outlet air:gas stream
2. quality characteristics: none

E. FE-3 - Air:Gas Flow Element

1. objectives: monitor flow rate of air:gas stream
2. quality characteristics: none

F. FE-4 - Caustic Water Flow Element

1. objectives: monitor flow rate of caustic water
2. quality characteristics: none

G. FV-18 - Caustic Water Feed Valve

1. objectives: throttle flow of caustic water to scrubber column
2. quality characteristics: none

H. FV-19 - Bottoms Drain Valve

1. objectives: throttle drain flow of caustic water from scrubber column
2. quality characteristics: none

I. LE-1 - Bottoms Level Element

1. objectives: monitor level of scrubber column bottoms
2. quality characteristics: none

J. PE-2 - Column Pressure Distribution Element(s)

1. objectives: monitor pressure gradient across scrubber column
2. quality characteristics: none

K. TE-8 - Column Temperature Distribution Element(s)

1. objectives: monitor temperature gradient across scrubber column
2. quality characteristics: none

L. TE-9 - Caustic Water Feed Temperature Element

1. objectives: monitor temperature of caustic water feed
2. quality characteristics: none

M. JS-11 - Air Exhaust Blower Power Switch

1. objectives: start/stop blower
2. quality characteristics: air flow rate

IV. Integration - see Level 2 Control Coordination Drawing, Internal, figure A-13

A. directive (IDLE) => STARTUP and IDLE

STARTUP

1. set column mixing characteristic
   a. task [CS-1: bubble hole plugs] to meet parameter (effective bubble area)
2. fill column
   a. query [FE-4: flow]
   b. task [FV-18: position] to meet parameter (caustic water flow rate)
   c. query [LE-1: bottoms level]
   d. task [FV-19: position] to meet parameter (bottoms level)

IDLE

3. report (status; mode=idle)

B. directive (NORMAL) => INITIATION and NORMAL

INITIATION

1. start air flow
   a. select belt combination on P-3 to meet parameter (air flow rate)
   b. task [JS-11: on]

NORMAL

2. report (status; mode=normal)
3. monitor column temperature
   a. query [TE-8: temperature distribution]
   b. record (temperature distribution profile)
4. monitor caustic water temperature
   a. query [TE-9: temperature]
   b. record (caustic water temperature)
5. monitor air flow

a. query [FE-3: flow]
b. record (air flow rate)
6. monitor air:gas compositions and report (nitroglycerin composition at outlet)
a. query [A-3: inlet composition]
b. query [A-4: outlet composition]
c. record (composition of inlet air:gas, composition of outlet air:gas)
d. determine nitroglycerin composition at outlet from composition of outlet air:gas
7. monitor column pressure
a. query [PE-2: pressure distribution]
b. record (pressure distribution profile)

C. directive (OFF) => SHUTDOWN and OFF

SHUTDOWN

1. stop air flow
a. task [JS-11: off]
2. empty column
a. task [FV-18: closed]
b. task [FV-19: position=open]
c. query [LE-1: bottoms level=empty]
d. task [FV-19: position=closed]

OFF

2. report (status, mode=off)

Block Designation: CCT - Caustic Circulate
Form 80311

Revision: 1 Date: Nov 1980 ARRADCOM - TSD - PROC CON SYS SEC

I. Interfaces

A. Directives

1. PRIMARY NORMAL
2. SECONDARY NORMAL
3. OFF

B. Reports

1. status
   a. operation mode (startup, primary normal, switchover, secondary normal, shutdown, off)
2. characteristics
   a. none

C. Information

1. records
   a. primary caustic water composition
   b. alternate caustic water composition
2. parameters
   a. none

D. Coordination

1. see Level 1 Control Coordination Drawing, Internal, figure A-11
2. see Level 2 Control Coordination Drawing, External, figure A-14

II. Transfer Relations

A. Directives / Operations

1. directive (PRIMARY NORMAL) => transition from OFF to PRIMARY NORMAL (STARTUP) and maintain PRIMARY NORMAL
2. directive (SECONDARY NORMAL) => transition from PRIMARY NORMAL to SECONDARY NORMAL (SWITCHOVER) and maintain SECONDARY NORMAL
3. directive (OFF) => transition from PRIMARY NORMAL to OFF (SHUTDOWN)
4. directive (OFF) => transition from SECONDARY NORMAL to OFF (SHUTDOWN) if SWITCHOVER performed

B. Inputs / Operations / Outputs

1. STARTUP, PRIMARY NORMAL and SECONDARY NORMAL => flow of I:2 and flow of O:1
2. flow of I:2 => increasing contents
3. flow of O:1 => decreasing contents
4. SHUTDOWN => flow of O:2
5. flow of O:2 => decreasing contents

C. Free Boundaries

1. flow of I:3 => increasing contents

2. flow of I:1 => increasing contents
3. composition of I:1, I:2 and I:3 => composition of O:1 and O:2

III. Decomposition of Block

A. TK-2/TK-3 - Primary/Alternate Caustic Water Reservoir

1. objectives: provide volume buffer for caustic water
2. quality characteristics: minimal composition variation

B. P-5/P-6 - Primary/Alternate Caustic Circulation Pump

1. objectives: transfer caustic water from reservoir to caustic scrubber
2. quality characteristics: none

C. FV-20/FV-21 - Primary/Alternate Caustic Water Fill Valve

1. objectives: throttle flow of caustic water to reservoir
2. quality characteristics: none

D. FV-22/FV-23 - Primary/Alternate Makeup Water Valve

1. objectives: throttle flow of makeup water to reservoir
2. quality characteristics: none

E. FV-24/FV-25 - Primary/Alternate Circuit Selection Valve

1. objectives: connect reservoir to circulation pump
2. quality characteristics: none

F. FV-26/FV-27 - Primary/Alternate Caustic Water Drain Valve

1. objectives: enable draining of reservoir
2. quality characteristics: none

G. FV-28 - Return Circuit Selection Valve

1. objectives: connect circuit return to reservoir
2. quality characteristics: none

H. JS-9/JS-10 - Primary/Alternate Caustic Circulation Pump Switch

1. objectives: start/stop pump operation
2. quality characteristics: none

I. LS-5/LS-6 - Primary/Alternate Caustic Water Reservoir Level Switch

1. objectives: monitor level of caustic water in reservoir
2. quality characteristics: none

J. A-1/A-2 - Primary/Alternate Caustic Water Composition Analyzer

1. objectives: monitor composition of caustic water in reservoir
2. quality characteristics: none

Block Designation: CCT - Caustic Circulate
Form 80311

IV. Integration - see Level 2 Control Coordination Drawing, Internal, figure A-14

A. directive (PRIMARY NORMAL) => STARTUP and PRIMARY NORMAL

STARTUP

1. fill block
   a. task [FV-20: open], task [FV-21: open]
   b. query [LS-5: level=full], then task [FV-20: closed]
   c. query [LS-6: level=full], then task [FV-21: closed]
2. establish circulation in primary circuit
   a. task [FV-24: open]
   b. task [JS-9: on]
   c. task [FV-28: position to primary caustic water reservoir]

PRIMARY NORMAL

4. report (status; mode=normal)
5. maintain primary reservoir contents
   a. query [LS-5: level=full]
   b. task [FV-22: position] to meet (level=full)
6. monitor reservoir composition
   a. query [A-1: caustic water composition]
   b. record (primary caustic water composition)

B. directive (SECONDARY NORMAL) => SWITCHOVER and SECONDARY NORMAL

SWITCHOVER

1. start alternate circuit and stop primary circuit
   a. task [FV-25: open]
   b. task [JS-10: on]
   c. task [FV-28: position to alternate caustic water reservoir]
   d. task [FV-24: closed]
   e. task [FV-22: closed]
   f. task [JS-9: off]

SECONDARY NORMAL

2. report (status; mode=secondary normal)
3. maintain alternate reservoir contents
   a. query [LS-6: level=full]
   b. task [FV-23: position] to meet (level=full)
4. monitor alternate reservoir composition
   a. query [A-2: composition]
   b. record (alternate caustic water composition)

C. directive (OFF) => SHUTDOWN and OFF

PRIMARY SHUTDOWN

1. stop and empty primary caustic water reservoir
   a. task [FV-24: closed]
   b. task [FV-22: closed]
   c. task [JS-9: off]

d. task [FV-26: open]
e. query [LS-5: level=empty], then task [FV-26: closed]

SECONDARY SHUTDOWN

2. stop and empty alternate caustic water reservoir
   a. task [FV-25: closed]
   b. task [FV-23: closed]
   c. task [JS-10: off]
   d. task [FV-27: open]
   e. query [LS-6: level=empty], then task [FV-27: closed]

OFF

3. report (status; mode=off)

Block Designation: CSP - Caustic Solution Preparation
Form 80311

Revision: 1 Date: Nov 1980 ARRADCOM - TSD - PROC CON SYS SEC

I. Interfaces

A. Directives

1. BATCH
   a. batch size
2. OFF

B. Reports

1. status
   a. operation mode (startup, batch, shutdown, off)
2. characteristics
   a. none

C. Information

1. records
   a. none
2. parameters
   a. composition

D. Coordination

1. see Level 1 Control Coordination Drawing, Internal, figure A-11
2. see Level 2 Control Coordination Drawing, External, figure A-15

II. Transfer Relations

A. Directives / Operations

1. directive (BATCH) => transition from OFF to BATCH (STARTUP) and maintain BATCH
2. directive (OFF) => transition from BATCH to OFF (SHUTDOWN)

B. Inputs / Operations / Outputs

1. STARTUP => flow of I:1 and I:2
2. flow of I:1 and I:2 => increasing contents
3. flow and composition of I:1 and I:2 => composition of O:1
4. SHUTDOWN => flow of O:1
5. flow of O:1 => decreasing contents

C. Free Boundaries

1. none

III. Decomposition of Block

A. TK-7 - Caustic Solution Tank

1. objectives: supply holdup for dissolving caustic soda
2. quality characteristics: homogeneity of caustic water solution

B. AG-1 - Agitator

1. objectives: assist dissolution of caustic soda in water
2. quality characteristics: homogeneity of caustic water solution

C. P-11 - Caustic Supply Pump

1. objectives: transfer caustic water solution to caustic water reservoirs
2. quality characteristics: none

D. UPK - Unpackage Caustic Soda

1. objectives: deliver unpackaged caustic soda to caustic solution tank
2. quality characteristics: composition of caustic water solution

E. FV-16 - Water Feed Valve

1. objectives: throttle water filling of caustic solution tank
2. quality characteristics: none

F. FV-17 - Caustic Solution Drain Valve

1. objectives: connect caustic soltuion tank to caustic supply pump
2. quality characteristics: none

G. JS-7 - Agitator Power Switch

1. objectives: start/stop agitator
2. quality characteristics: none

H. JS-8 - Caustic Supply Pump Power Switch

1. objectives: start/stop caustic supply pump
2. quality characteristics: none

I. LE-3 - Caustic Solution Level Element

1. objectives: monitor caustic solution level
2. quality characteristics: none

IV. Integration - see Level 2 Control Coordination Drawing, Internal, figure A-15

A. directive (BATCH) => STARTUP and BATCH

STARTUP

1. establish water heel
   a. task [FV-16: open]
   b. query [LE-3: level=directive(batch size)], then task [FV-16: closed]

BATCH

2. mix solution
   a. task [JS-7: on]

b. determine amount of caustic soda from parameter (composition) and directive (batch size)
c. task [UPK: ON; amount of caustic soda]
d. task [UPK: OFF]
e. task [JS-7: off]
3. report (status; mode=batch)

B. directive (OFF) => SHUTDOWN and OFF

SHUTDOWN

1. transfer caustic water solution
   a. task [FV-17: open]
   b. task [JS-8: on]
   c. query [LE-3: level=empty], then task [JS-8: off] and task [FV-17: closed]

OFF

2. report (status; mode=off)

Block Designation: SRB - Solvent Removal Bypass
Form 80311

Revision: 1 Date: Nov 1980 ARRADCOM - TSD - PROC CON SYS SEC

I. Interfaces

A. Directives

1. NORMAL
2. BYPASS

B. Reports

1. status
   a. operation mode (startup, normal, shutdown, off)
2. characteristics
   a. none

C. Information

1. records
   a. none
2. parameters
   a. none

D. Coordination

1. see Level 0 Control Coordination Drawing, Internal, figure A-5
2. see Level 1 Control Coordination Drawing, External, figure A-16

II. Transfer Relations

A. Directives / Operations

1. directive (NORMAL) => transition from BYPASS to NORMAL and maintain NORMAL
2. directive (BYPASS) => transition from NORMAL to BYPASS and maintain BYPASS

B. Inputs / Operations / Outputs

1. flow of I:1 and NORMAL => flow of O:1
2. flow of I:1 and BYPASS => flow of O:2

C. Free Boundaries

1. composition and temperature of I:1 => composition and temperature of O:1 and composition and temperature of O:2

III. Decomposition of Block

A. FV-30 - Bypass Valve

1. objectives: select output flow path
2. quality characteristics: none

IV. Integration - see Level 1 Control Coordination Drawing, Internal, figure A-16

Block Designation: SRB - Solvent Removal Bypass
Form 80311

A. directive (NORMAL) => NORMAL

NORMAL

1. select normal output
   a. task [FV-30: position to solvent removal]

B. directive (BYPASS) => BYPASS

BYPASS

1. select bypass output
   a. task [FV-30: position to atmosphere]

Block Designation: SVR - Solvent Removal
Form 80311

Revision: 1 Date: Nov 1980 ARRADCOM - TSD - PROC CON SYS SEC

I. Interfaces

A. Directives

1. NORMAL
2. IDLE
3. HOLD
4. OFF

B. Reports

1. status
   a. operation mode (startup, idle, initiate, normal, suspend, hold, resume, shut-down, off)
2. characteristics
   a. none

C. Information

1. records
   a. none
2. parameters
   a. none

D. Coordination

1. see Level 0 Control Coordination Drawing, Internal, figure A-5
2. see Level 1 Control Coordination Drawing, External, figure A-17

II. Transfer Relations

A. Directives / Operations

1. directive (IDLE) => transition from OFF to IDLE (STARTUP) and maintain IDLE
2. directive (NORMAL) => transition from IDLE to NORMAL (INITIATE) and maintain NORMAL
3. directive (HOLD) => transition from NORMAL to HOLD (SUSPEND) and maintain HOLD
4. directive (IDLE) => transition from HOLD to IDLE (RESUME) and maintain IDLE
5. directive (OFF) => transition from HOLD to OFF (SHUTDOWN)

B. Inputs / Operations / Outputs

1. STARTUP => flow of I:2
2. NORMAL => flow of I:2 and flow of O:2
3. SHUTDOWN => flow of O:2
4. flow, composition, temperature of I:1 and NORMAL => flow, composition, temperature of O:1 and composition and temperature of O:2

C. Free Boundaries

1. none

Block Designation: SVR - Solvent Removal
Form 80311

III. Decomposition of Block

A. SVA - Solvent Absorption

1. objectives: absorb solvents from air:gas stream into chilled water stream
2. quality characteristics: composition of air:gas stream

B. SVS - Solvent Storage

1. objectives: provide volume buffer for solvent solution
2. quality characteristics: minimal composition variation

C. WCH - Water Chiller

1. objectives: supply chilled water to SVA
2. quality characteristics: water temperature

IV. Integration - see Level 1 Control Coordination Drawing, Internal, figure A-17

A. directive (IDLE) => STARTUP and IDLE

STARTUP

1. prepare water supply
   a. task [WCH: NORMAL]

IDLE

2. report (status; mode=idle)
   a. query [WCH: status; mode=normal]

B. directive (NORMAL) => INITIATION and NORMAL

INITIATION

1. start absorber and setup solution storage
   a. task [SVA: NORMAL]
   b. task [SVS: NORMAL]

NORMAL

2. report (status; mode=normal)
   a. query [SVA: status; mode=normal]
   b. query [SVS: status; mode=normal]

C. directive (HOLD) => SUSPEND and HOLD

SUSPEND

1. hold water supply
   a. task [WCH: HOLD]
2. stop absorber and empty solvent storage
   a. task [SVA: OFF]
   b. task [SVS: OFF]

Block Designation: SVR - Solvent Removal
Form 80311

HOLD

3. report (status; mode=hold)

D. directive (IDLE) => RESUME and IDLE

RESUME

1. reestablish water supply
   a. task [WCH: NORMAL]

IDLE

2. report (status; mode=idle)
   a. query [WCH: status; mode=normal]

E. directive (OFF) => SHUTDOWN and OFF

SHUTDOWN

1. empty water supply
   a. task [WCH: OFF]

OFF

2. report (status; mode=off)

Block Designation: SVA - Solvent Absorption
Form 80311

Revision: 1 Date: Nov 1980 ARRADCOM - TSD - PROC CON SYS SEC

I. Interfaces

A. Directives

1. NORMAL
2. OFF

B. Reports

1. status
   a. operation mode (startup, normal, shutdown, off)
2. characteristics
   a. none

C. Information

1. records
   a. pressure distribution profile
   b. temperature distribution profile
   c. air flow rate
   d. chilled water temperature
   e. composition of outlet air:gas stream
2. parameters
   a. bottoms level
   b. chilled water flow rate

D. Coordination

1. see Level 1 Control Coordination Drawing, Internal, figure A-17
2. see Level 2 Control Coordination Drawing, External, figure A-18

II. Transfer Relations

A. Directives / Operations

1. directive (NORMAL) => transition from OFF to NORMAL (STARTUP) and maintain NOR-MAL
2. directive (OFF) => transition from NORMAL to OFF (SHUTDOWN)

B. Inputs / Operations / Outputs

1. STARTUP => flow of I:2
2. NORMAL => flow of I:2 and O:2
3. composition and flow of I:1 and NORMAL => composition of O:1
4. SHUTDOWN => flow of O:2

C. Free Boundaries

1. flow of I:1 => flow of O:1

III. Decomposition of Block

Block Designation: SVA - Solvent Absorption
Form 80311

A. P-8 - Absorber Bottoms Pump

1. objectives: transfer solvent solution from absorber bottoms
2. quality characteristics: none

B. SA-1 - Solvent Absorber

1. objectives: bring air:gas stream into contact with chilled water stream
2. quality characteristics: composition of air:gas stream

C. A-5 - Air:Gas Composition Analyzer

1. objectives: monitor composition of outlet air:gas stream
2. quality characteristics: none

D. FE-2 - Air Flow Rate Element

1. objectives: monitor flow rate of air:gas stream
2. quality characteristics: none

E. FE-5 - Chilled Water Flow Element

1. objectives: throttle flow of chilled water to SA-1
2. quality characteristics: none

F. FV-10 - Chilled Water Flow Valve

1. objectives: throttle chilled water feed to absorber
2. quality characteristics: none

G. FV-11 - Bottoms Flow Valve

1. objectives: throttle flow of bottoms from absorber
2. quality characteristics: none

H. JS-3 - Absorber Bottoms Pump Power Switch

1. objectives: start/stop absorber bottoms pump
2. quality characteristics: none

I. LE-2 - Bottoms Level Element

1. objectives: monitor level of absorber bottoms
2. quality characteristics: none

J. PE-1 - Column Pressure Distribution Element(s)

1. objectives: monitor pressure gradient across absorber
2. quality characteristics: none

K. TE-6 - Chilled Water Inlet Temperature Element

1. objectives: monitor chilled water temperature
2. quality characteristics: none

L. TE-7 - Column Temperature Distribution Element(s)

1. objectives: monitor temperature gradient across absorber
2. quality characteristics: none

IV. Integration - see Level 2 Control Coordination Drawing, Internal, figure A-18.

A. directive (NORMAL) => STARTUP and NORMAL

STARTUP

1. fill column
   a. query [FE-5: flow]
   b. task [FV-10: position] to meet (flow = parameter (chilled water flow rate))
   c. task [JS-3: on]
   d. query [LE-2: bottoms level]
   e. task [FV-11: position] to meet parameter(bottoms level)

NORMAL

2. report (status; mode=normal)
3. monitor column temperature(s)
   a. query [TE-7: temperature distribution]
   b. record (temperature distribution profile)
4. monitor water temperature
   a. query [TE-6: temperature]
   b. record (water temperature)
5. monitor air flow
   a. query [FE-2: flow]
   b. report (air flow rate)
6. monitor outlet air:gas stream composition
   a. query [A-5: composition]
   b. record (composition of outlet air:gas stream)
7. monitor column pressure(s)
   a. query [PE-1: pressure distribution]
   b. record (pressure distribution profile)

B. directive (OFF) => SHUTDOWN and OFF

SHUTDOWN

1. empty column
   a. task [FV-10: closed]
   b. task [FV-11: open]
   c. query [LE-2: bottoms level=empty]
   d. task [JS-3: off]
   e. task [FV-11: closed]

OFF

2. report (status; mode=off)

Block Designation: SVS - Solvent Storage
Form 80311

Revision: 1 Date: Nov 1980 ARRADCOM - TSD - PROC CON SYS SEC

I. Interfaces

A. Directives

1. NORMAL
2. OFF

B. Reports

1. status
   a. operation mode (startup, normal, shutdown, off)
2. characteristics
   a. none

C. Information

1. records
   a. none
2. parameters
   a. none

D. Coordination

1. see Level 1 Control Coordination Drawing, Internal, figure A-17
2. see Level 2 Control Coordination Drawing, External, figure A-19

II. Transfer Relations

A. Directives / Operations

1. directive (NORMAL) => transition from OFF to NORMAL (STARTUP) and maintain NORMAL
2. directive (OFF) => transition from NORMAL to OFF (SHUTDOWN)

B. Inputs / Operations / Outputs

1. NORMAL and contents=full => flow of O:1
2. flow of O:1 => decreasing contents

C. Free Boundaries

1. flow of I:1 => increasing contents

III. Decomposition of Block

A. P-9/P-10 - Primary/Secondary Solvent Solution Transfer Pump

1. objectives:
2. quality characteristics:

B. TK-5/TK-6 - Primary/Secondary Solvent Solution Buffer Tank

1. objectives:
2. quality characteristics:

C. FV-12/FV-13 - Primary/Secondary Diverter Valve

1. objectives:
2. quality characteristics:

D. FV-14/FV-15 - Primary/Secondary Buffer Tank Drain Valve

1. objectives:
2. quality characteristics:

E. JS-4/JS-5 - Primary/Secondary Solvent Solution Transfer Pump Power Switch

1. objectives:
2. quality characteristics:

F. LS-3/LS-4 - Primary/Secondary Solvent Solution Buffer Tank Level Switch

1. objectives:
2. quality characteristics:

IV. Integration - see Level 2 Control Coordination Drawing, Internal, figure A-19

A. directive (NORMAL) => STARTUP and NORMAL

STARTUP

1. set two stage configuration
   a. task [FV-12: position to TK-5]
   b. task [FV-13: position to TK-6]

NORMAL

2. report (status; mode=normal)
3. accumulate primary batches of solvent solution
   a. query [LS-3: level=full]
   b. task [FV-14: open]
   c. task [JS-4: on]
   d. query [LS-3: level=empty]
   e. task [FV-14: closed]
   f. task [JS-4: off]
4. accumulate secondary batches of solvent solution
   a. query [LS-4: level=full]
   b. task [FV-15: open]
   c. task [JS-5: on]
   d. query [LS-4: level=empty]
   e. task [FV-15: closed]
   f. task [JS-5: off]

B. directive (OFF) => SHUTDOWN and OFF

SHUTDOWN

Block Designation: SVS - Solvent Storage
Form 80311

1. empty primary buffer
   a. task [FV-14: open]
   b. task [JS-4: on]
   c. query [LS-3: level=empty]
   d. task [FV-14: closed]
   e. task [JS-4: off]
2. empty secondary buffer
   a. task [FV-15: open]
   b. task [JS-5: on]
   c. query [LS-4: level=empty]
   d. task [FV-15: closed]
   e. task [JS-5: off]

OFF

3. report (status; mode=off)

Block Designation: WCH - Water Chiller
Form 80311

Revision: 1 Date: Nov 1980 ARRADCOM - TSD - PROC CON SYS SEC

I. Interfaces

A. Directives

1. NORMAL
2. HOLD
3. OFF

B. Reports

1. status
   a. operation mode (startup, normal, suspend, hold, resume, shutdown, off)
2. characteristics
   a. none

C. Information

1. records
   a. none
2. parameters
   a. water temperature

D. Coordination

1. see Level 1 Control Coordination Drawing, Internal, figure A-17
2. see Level 2 Control Coordination Drawing, External, figure A-20

II. Transfer Relations

A. Directives / Operations

1. directive (NORMAL) => transition from OFF to NORMAL (STARTUP) and maintain NORMAL
2. directive (HOLD) => transition from NORMAL to HOLD (SUSPEND) and maintain HOLD
3. directive (NORMAL) => transition from HOLD to NORMAL (RESUME) and maintain NORMAL
4. directive (OFF) => transition from HOLD to OFF (SHUTDOWN)

B. Inputs / Operations / Outputs

1. STARTUP => flow of I:1
2. NORMAL and decreasing contents => flow of I:1
3. flow of I:1 => increasing contents

C. Free Boundaries

a. flow of O:1 => decreasing contents

III. Decomposition of Block

A. CH-1 - Chiller

Block Designation: WCH - Water Chiller
Form 80311

1. objectives: chill water for solvent absorber
2. quality characteristics: temperature of chilled water

B. P -7 - Water Supply Pump

1. objectives: transfer water from water supply tank to chiller
2. quality characteristics: none

C. TK-4 - Water Supply Tank

1. objectives: supply water storage
2. quality characteristics: none

D. FV-7 - Water Inlet Flow Valve

1. objectives: throttle filling of water supply tank
2. quality characteristics: none

E. FV-8 - Chiller Bypass Valve

1. objectives: direct water flow around chiller
2. quality characteristics: none

F. FV-9 - Water Supply Tank Drain Valve

1. objectives: throttle drain flow from water supply tank
2. quality characteristics: none

G. JS-2 - Water Supply Pump Power Switch

1. objectives: start/stop water supply pump
2. quality characteristics: none

H. LS-2 - Water Supply Tank Level Switch

1. objectives: monitor water supply level
2. quality characteristics: none

I. TE-5 - Water Supply Tank Temperature Element

1. objectives: monitor water supply temperature
2. quality characteristics: none

IV. Integration - see Level 2 Control Coordination Drawing, Internal, figure A-20

A. directive (NORMAL) => STARTUP and NORMAL

STARTUP

1. fill block
   a. query [LS-2: level=full]
   b. task [FV-7: position] to meet (level=full)
2. establish water supply delivery
   a. task [JS-2: on]

3. establish water temperature
   a. query [TE-5: temperature]
   b. if temperature > parameter(water temperature), then task [CH-1: on; parameter(water temperature)] and task [FV-8: position to chiller]
   c. if temperature < parameter(water temperature), then task [FV-8: position to bypass]

NORMAL

4. report (status; mode=normal)

D. directive (HOLD) => SUSPEND and HOLD

SUSPEND

1. disable fill and delivery
   a. task [FV-7: position=closed]
   b. task [JS-2: off]
   c. task [CH-1: off]

HOLD

2. report (status; mode=hold)

C. directive (NORMAL) => RESUME and NORMAL

RESUME

1. fill block
   a. query [LS-2: level=full]
   b. task [FV-7: position] to meet (level=full)
2. establish water supply delivery
   a. task [JS-2: on]
3. establish water temperature
   a. query [TE-5: temperature]
   b. if temperature > parameter(water temperature), then task [CH-1: on; parameter(water temperature)] and task [FV-8: position to chiller]
   c. if temperature < parameter(water temperature), then task [FV-8: position to bypass]

NORMAL

4. report (status; mode=normal)

D. directive (OFF) => SHUTDOWN and OFF

SHUTDOWN

1. empty block
   a. task [FV-9: open]
   b. query [LS-2: level=empty], then task [FV-9: closed]

OFF

Block Designation: WCH - Water Chiller
Form 80311

2. report (status; mode=off)

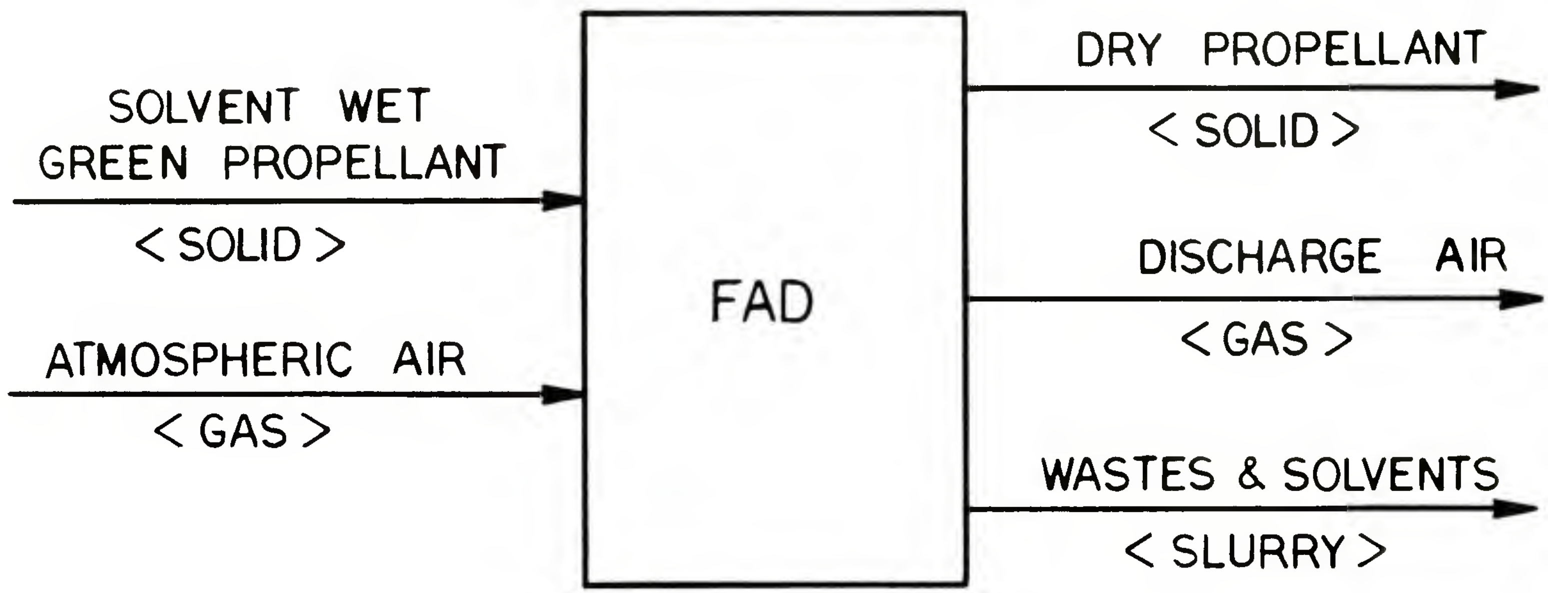


Figure A-1. Functional identification level 0 modernized forced air dry

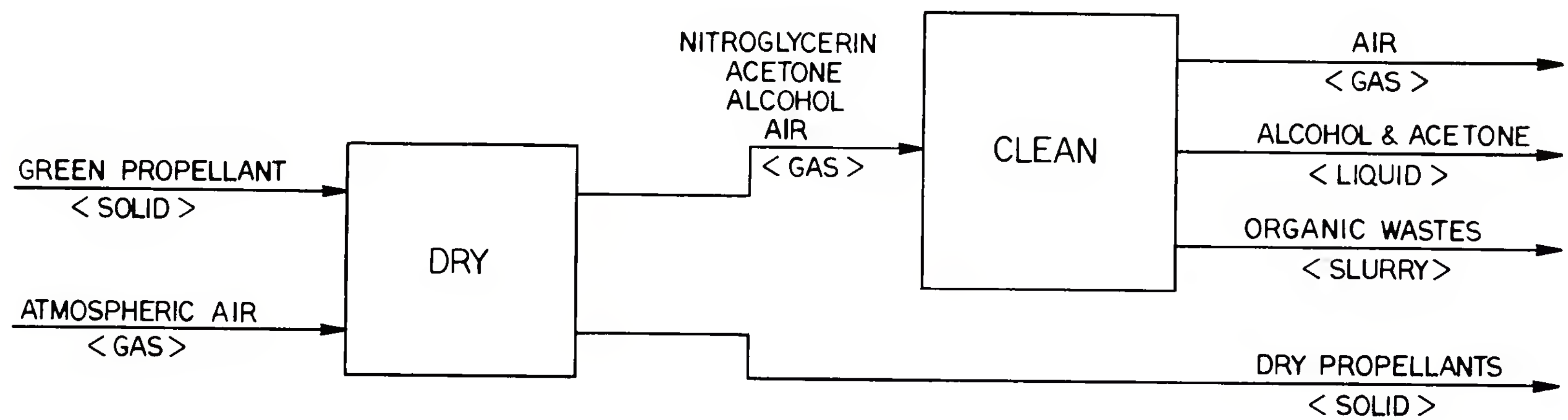


Figure A-2. Functional identification level 1 modernized forced air dry

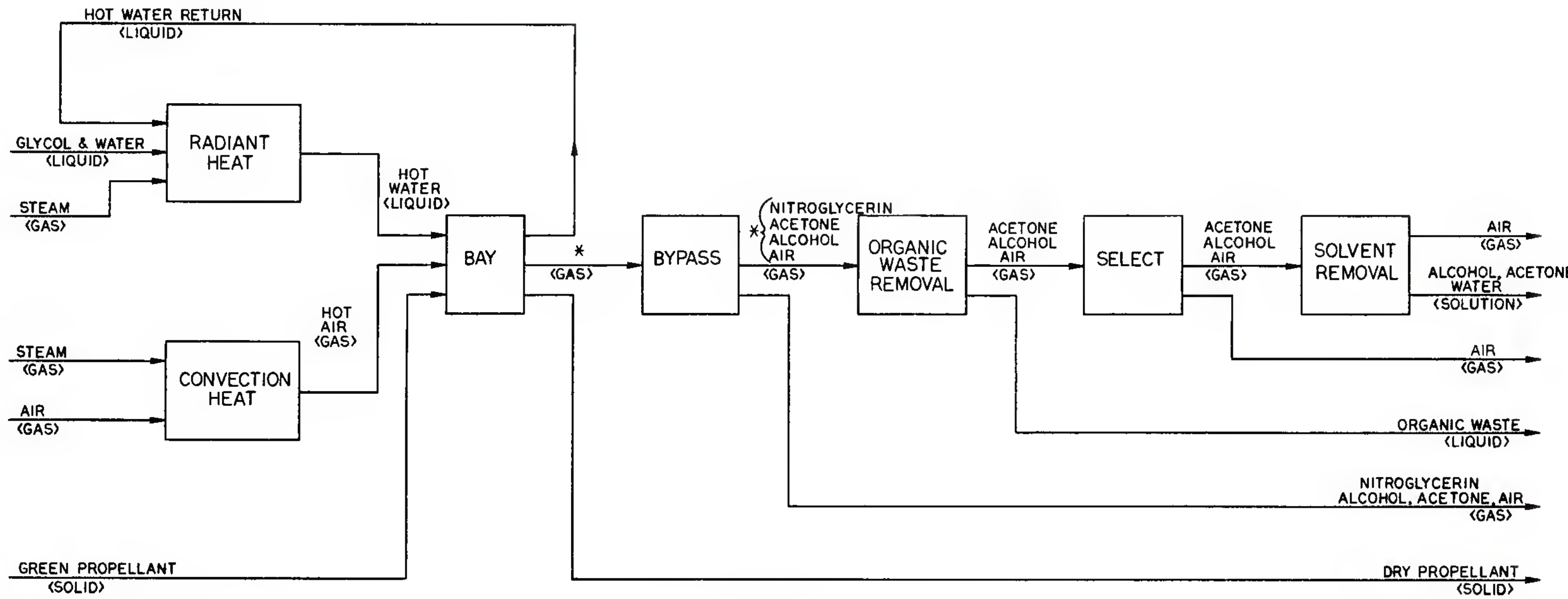


Figure A-3. Functional identification level 2 modernized forced air dry

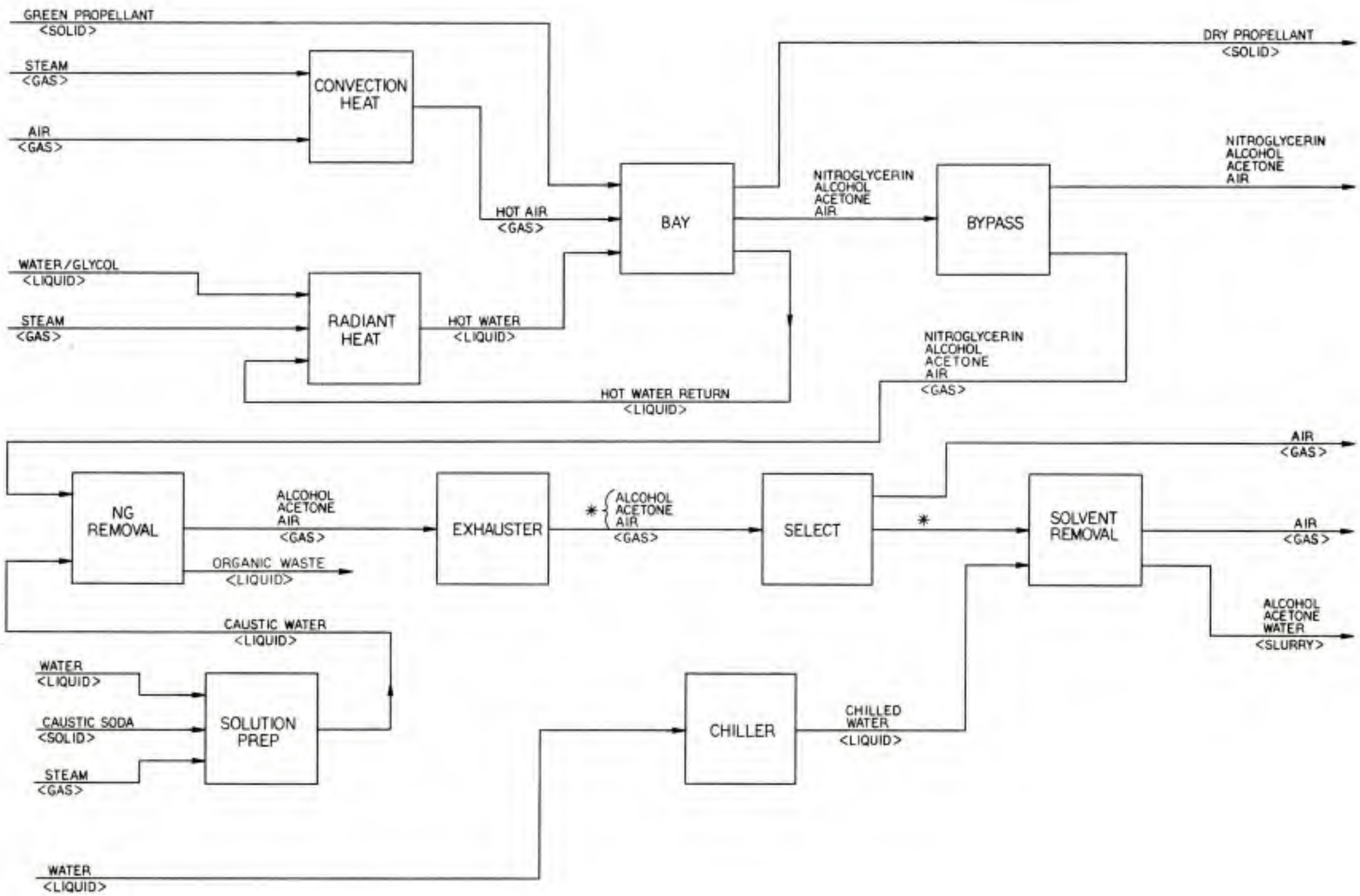


Figure A-4. Functional identification level 3 modernized forced air dry

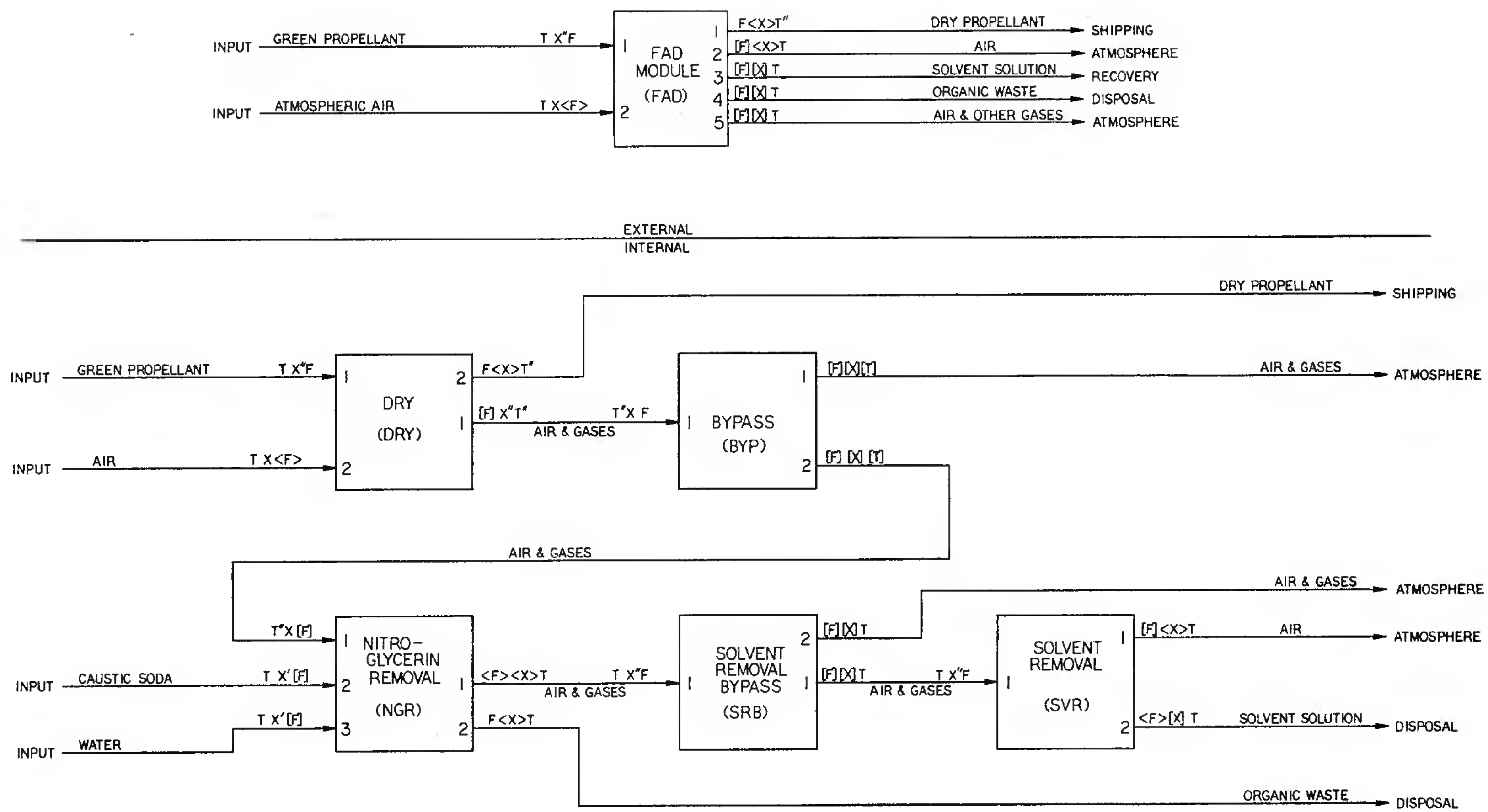


Figure A-5. Operational coordination level 0 modernized forced air dry

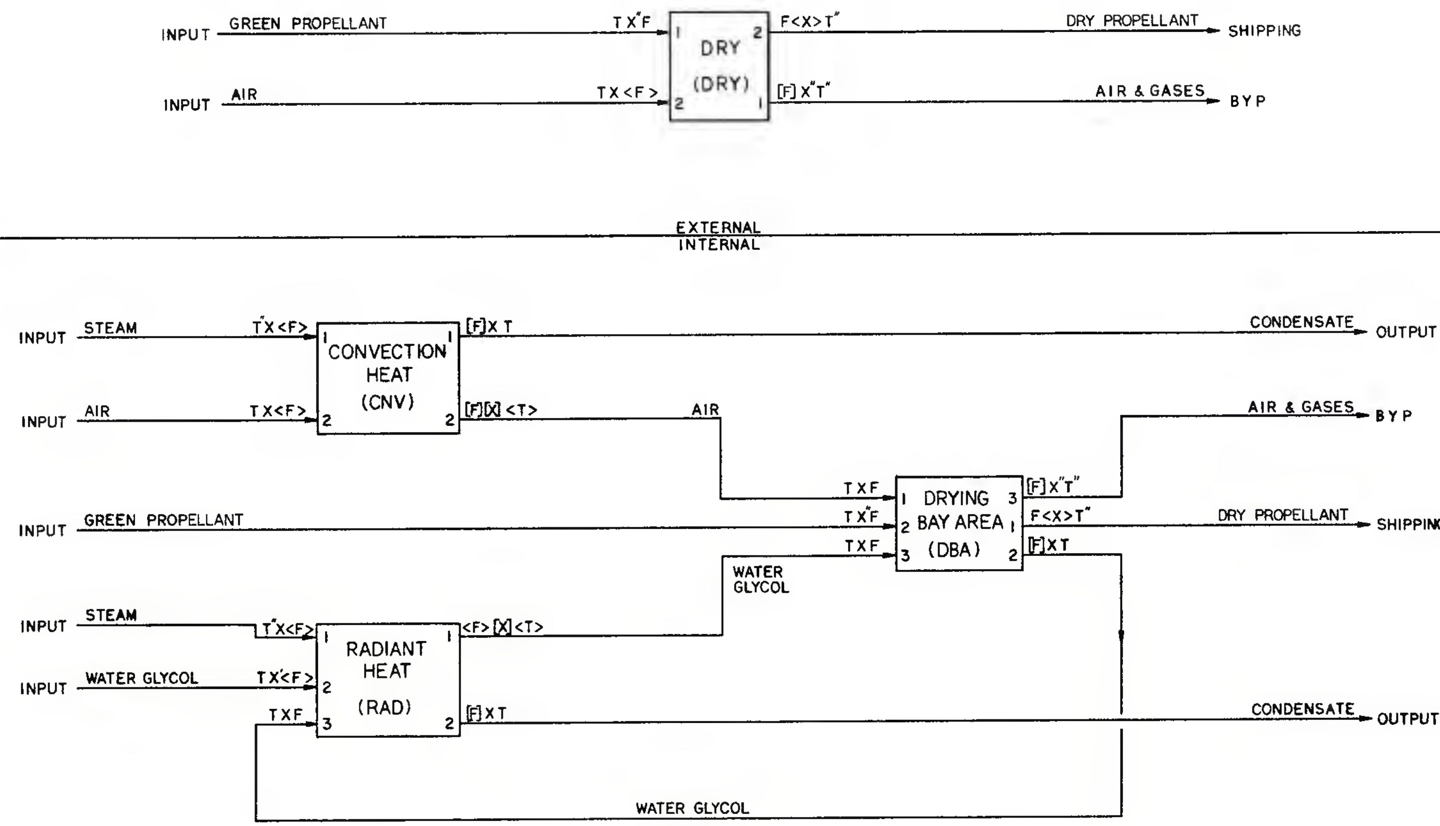


Figure A-6. Operational coordination level 1 modernized forced air dry

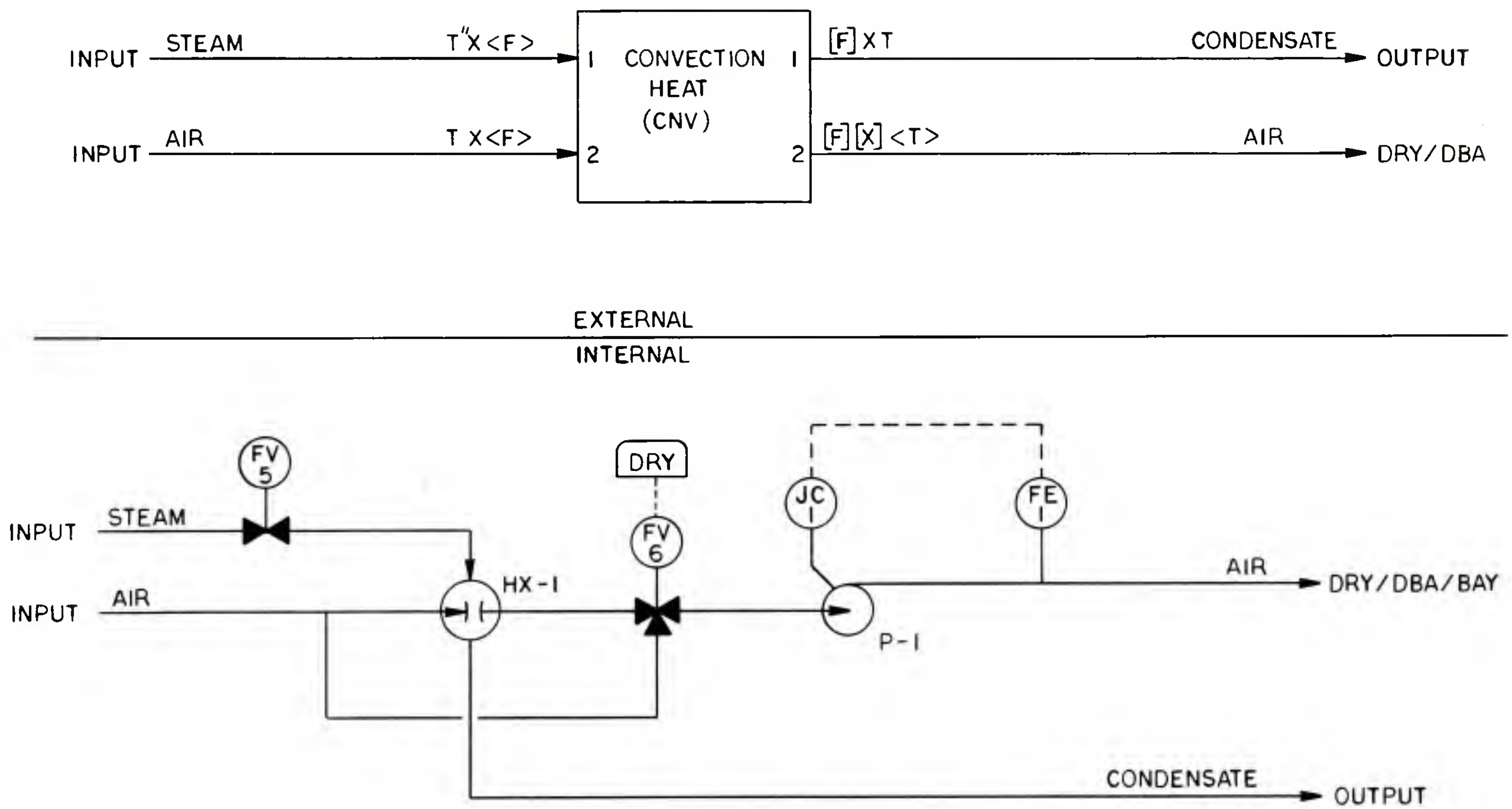


Figure A-7. Operational coordination level 2 modernized forced air dry

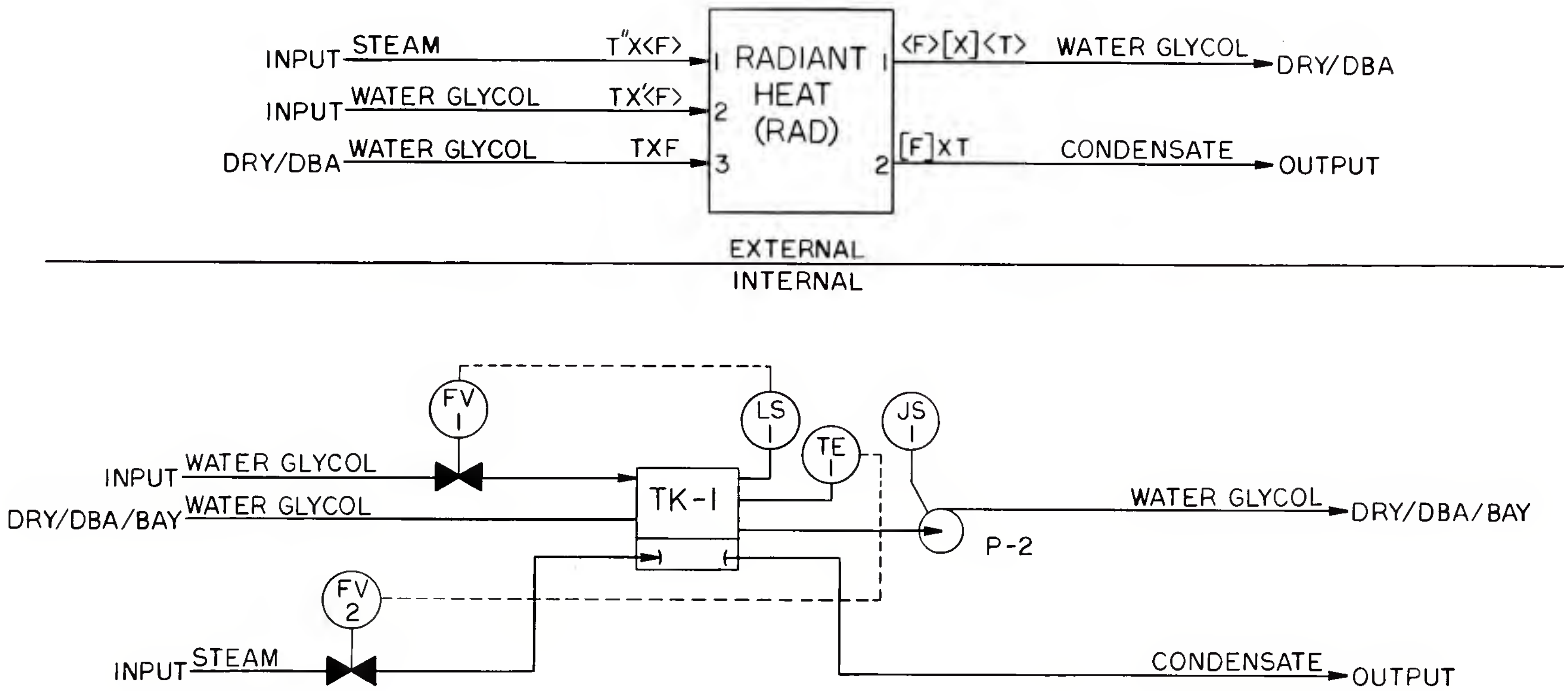


Figure A-8. Operational coordination level 2 modernized forced air dry

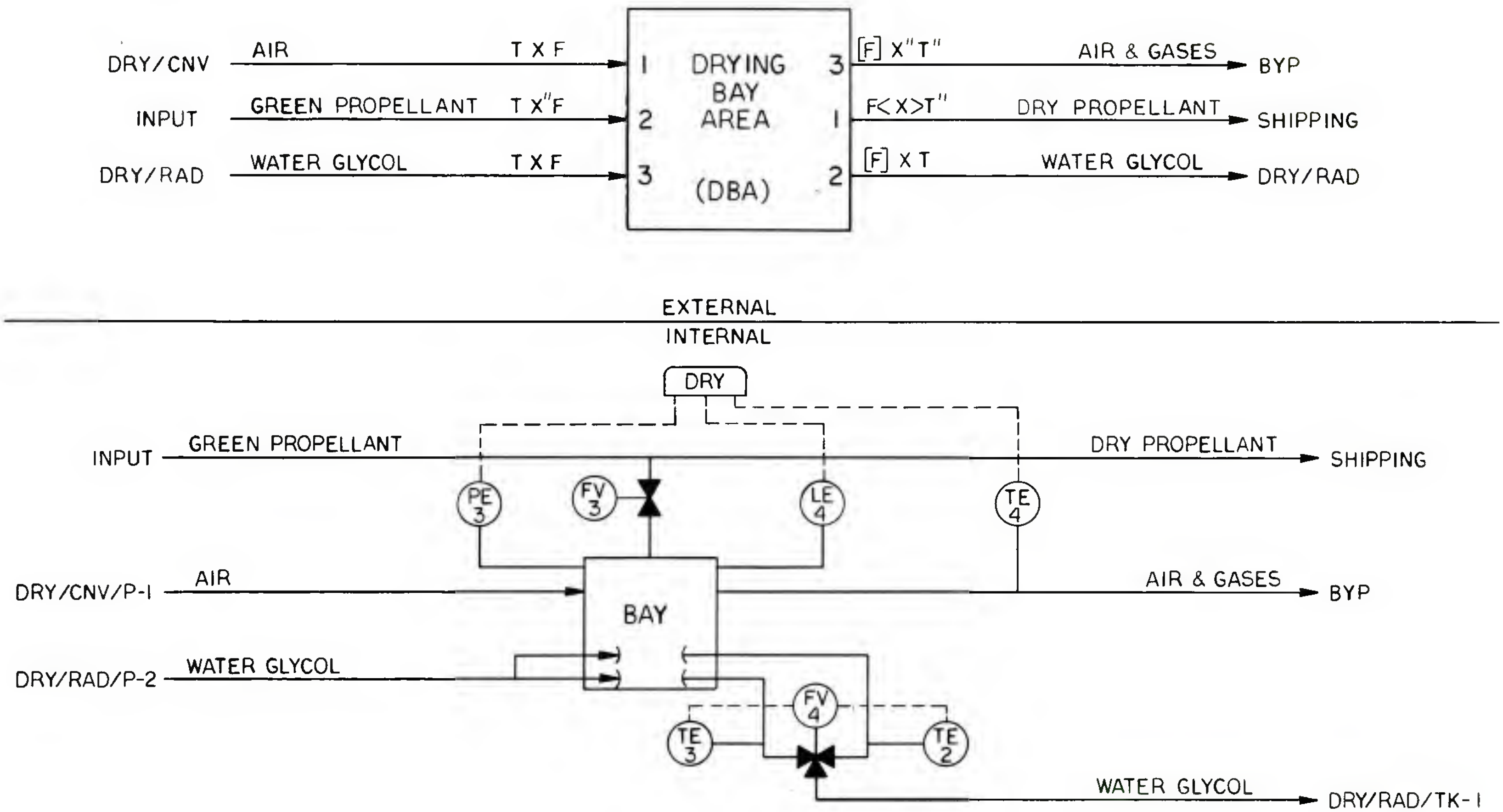


Figure A-9. Operational coordination level 2 modernized forced air dry

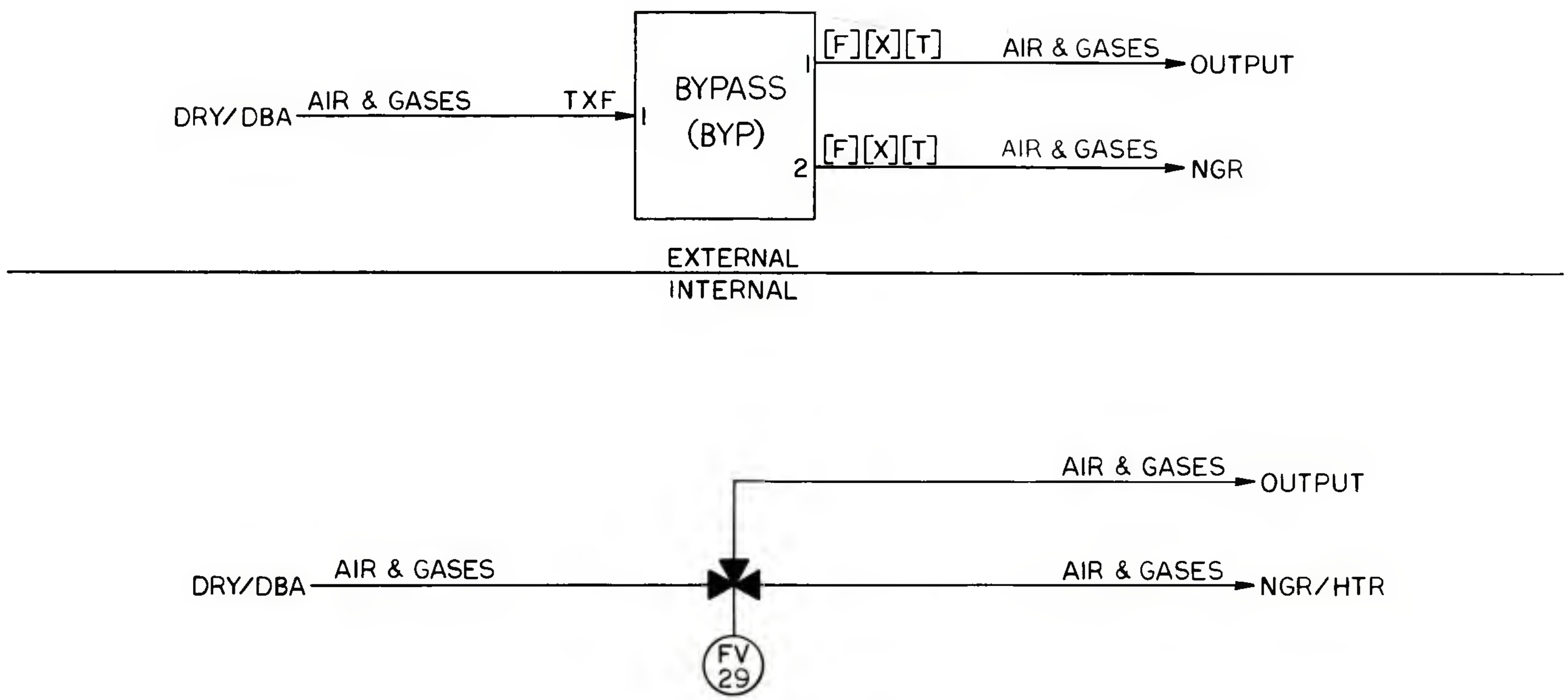


Figure A-10. Operational coordination level 1 modernized forced air dry

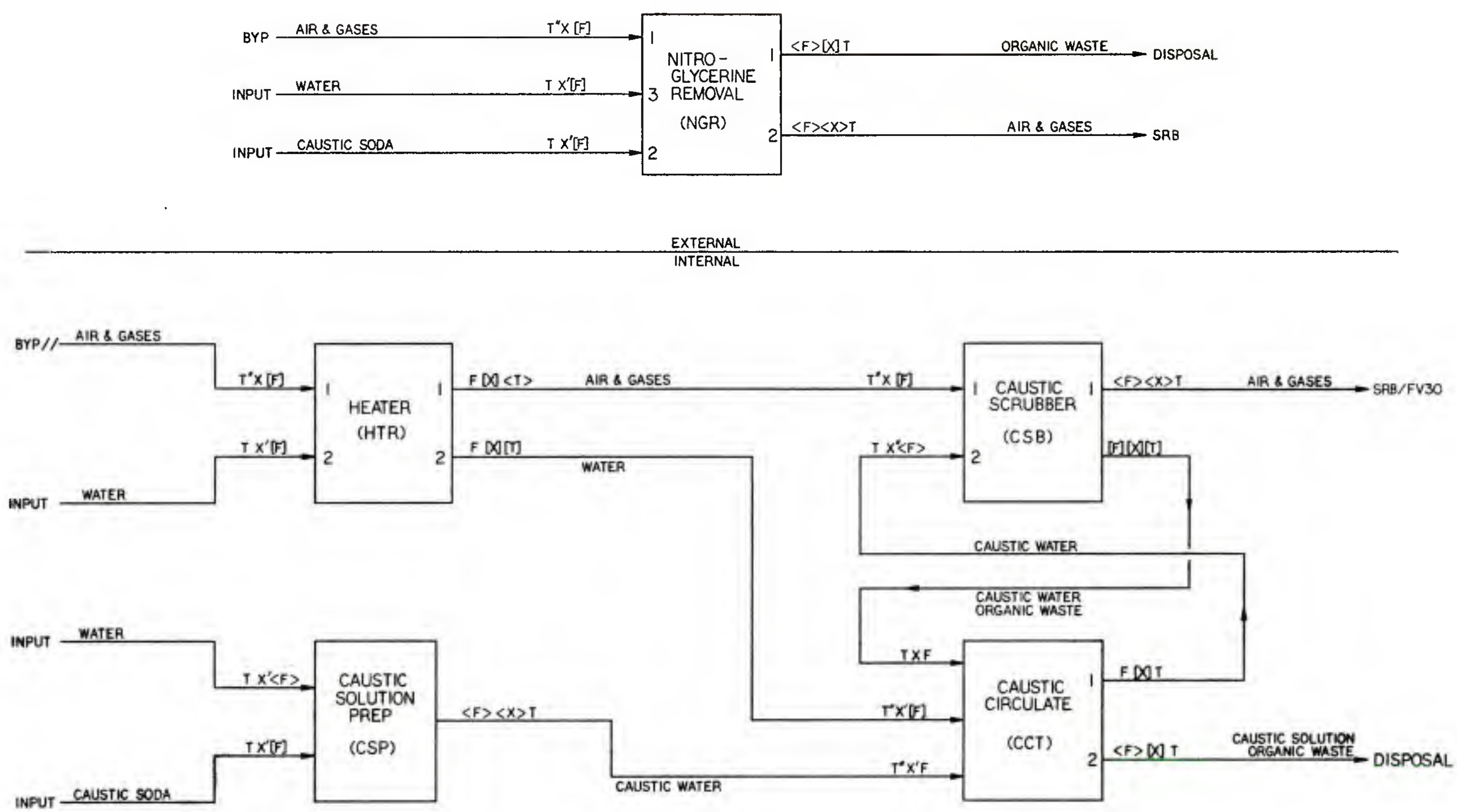


Figure A-11. Operational coordination level 1 modernized forced air dry

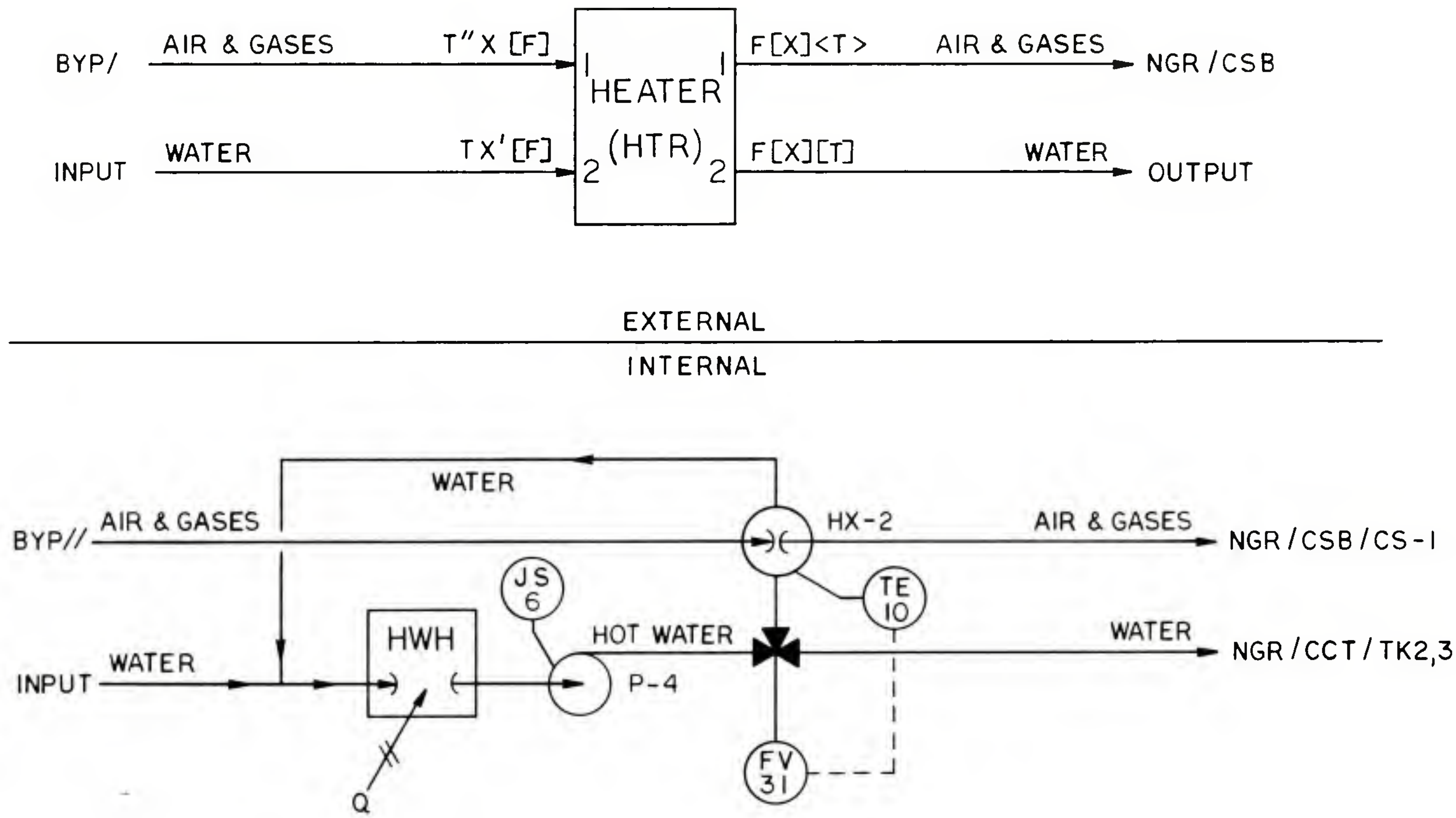
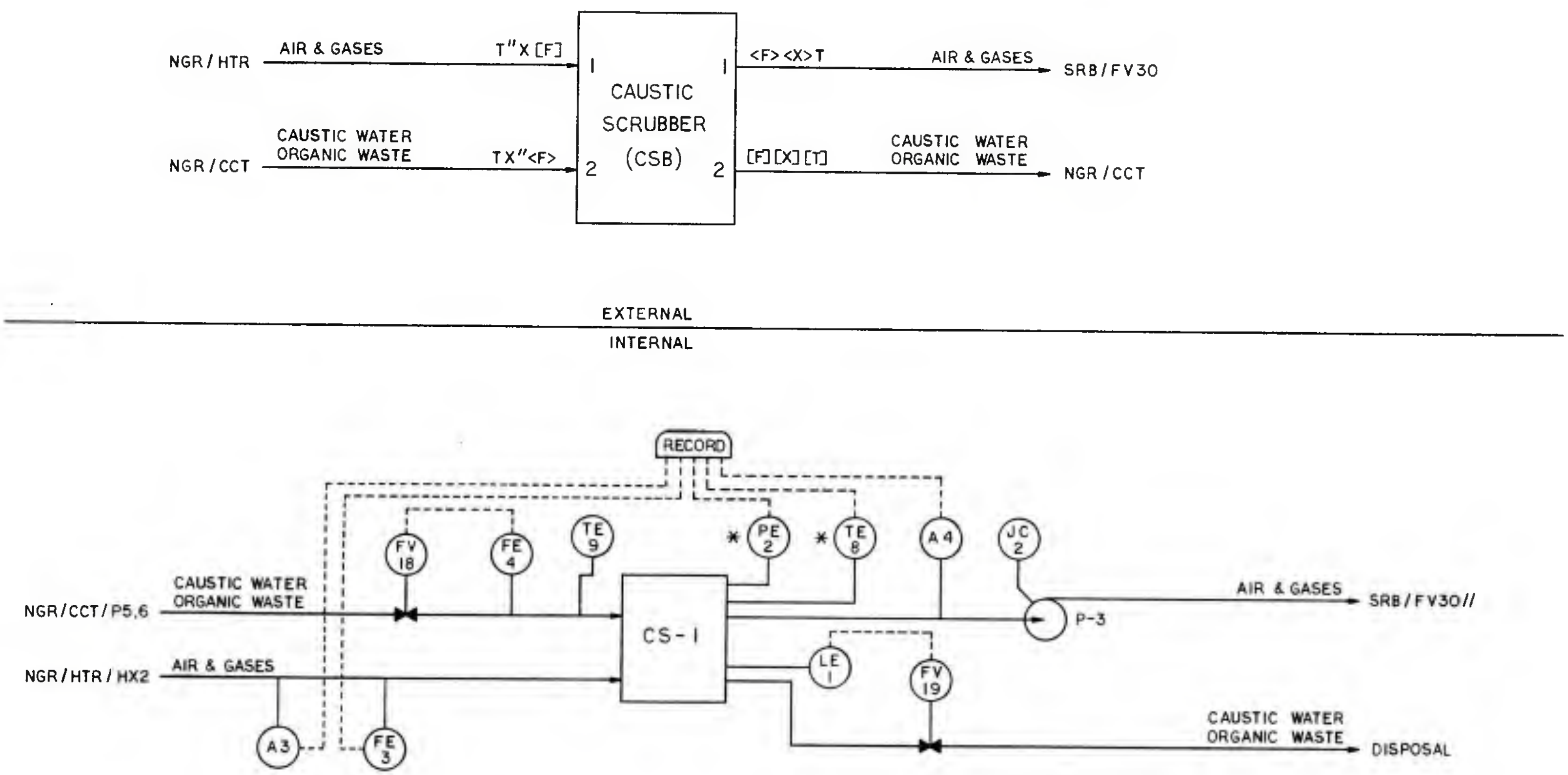


Figure A-12. Operational coordination level 2 modernized forced air dry



* NOTE: PE-2, COLUMN PRESSURE DISTRIBUTION SENSORS NUMBER TBD (PE-2 a····n)

TE-8, COLUMN TEMPERATURE DISTRIBUTION SENSORS NUMBER TBD (TE-8,a····n)

Figure A-13. Operational coordination level 2 modernized forced air dry

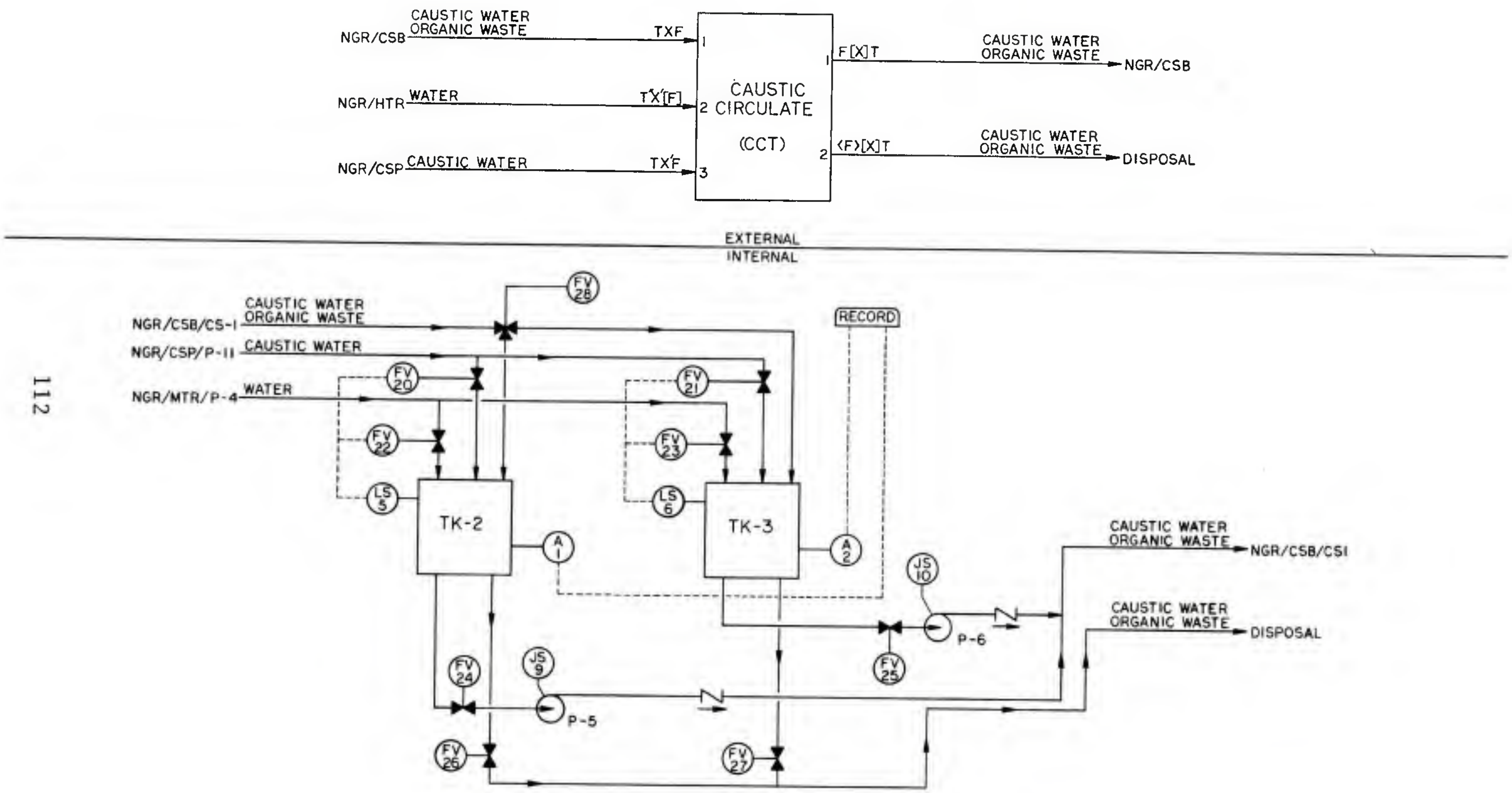


Figure A-14. Operational coordination level 2 modernized forced air dry

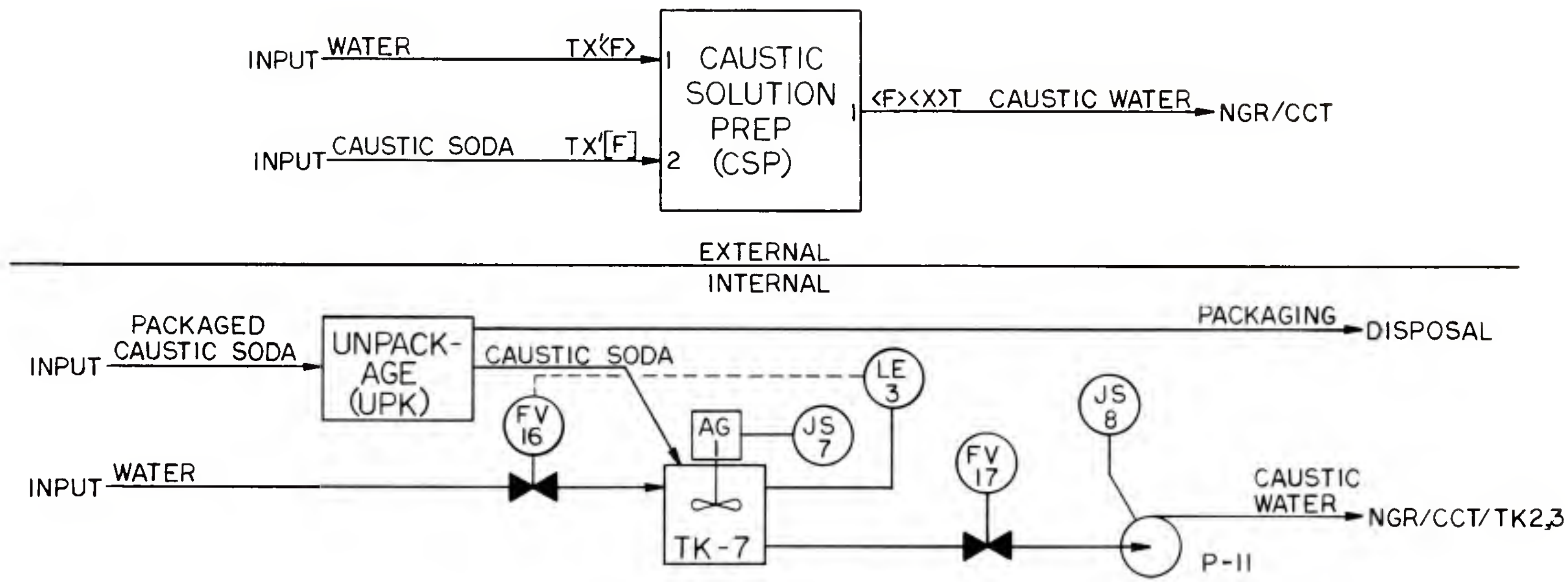


Figure A-15. Operational coordination level 2 modernized forced air dry

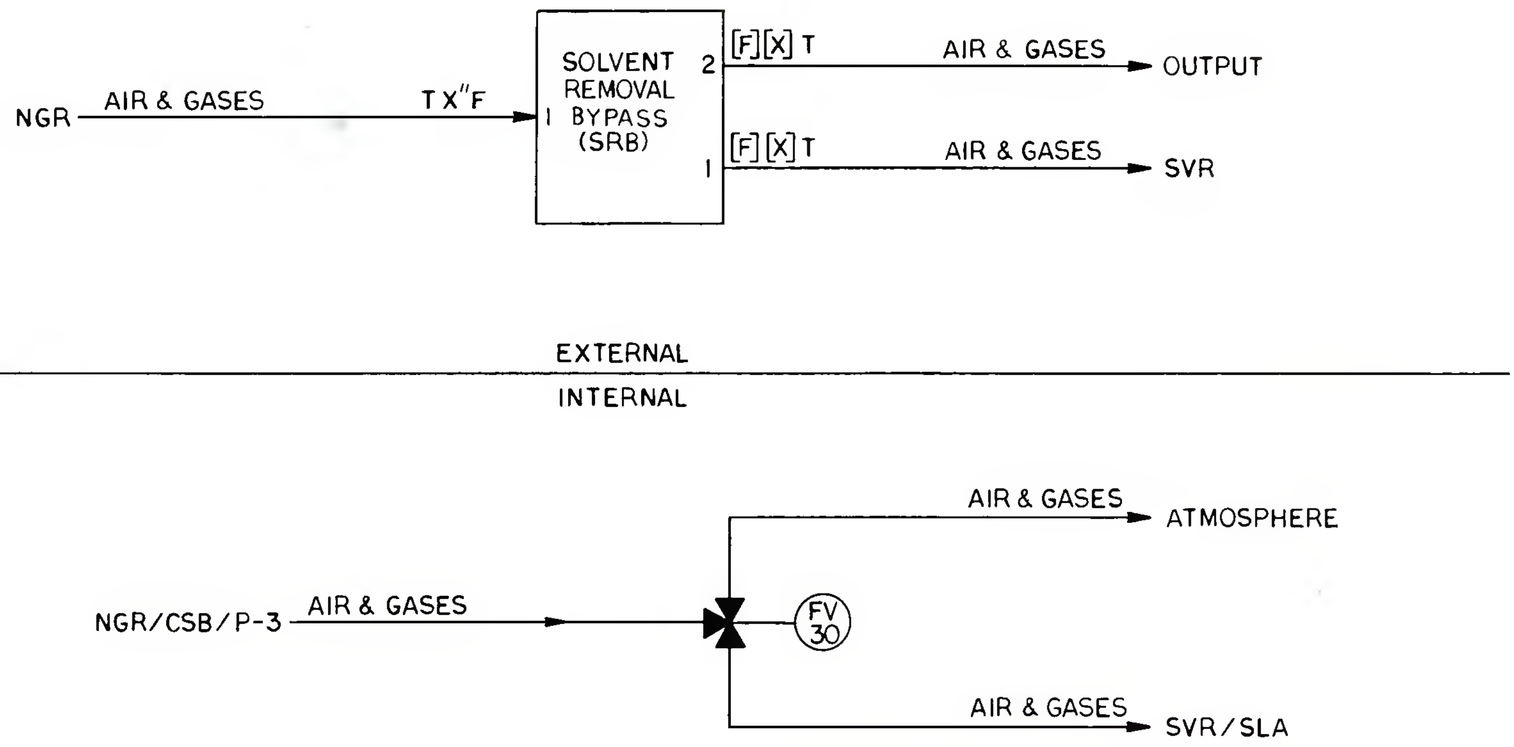


Figure A-16. Operational coordination level 1 modernized forced air dry

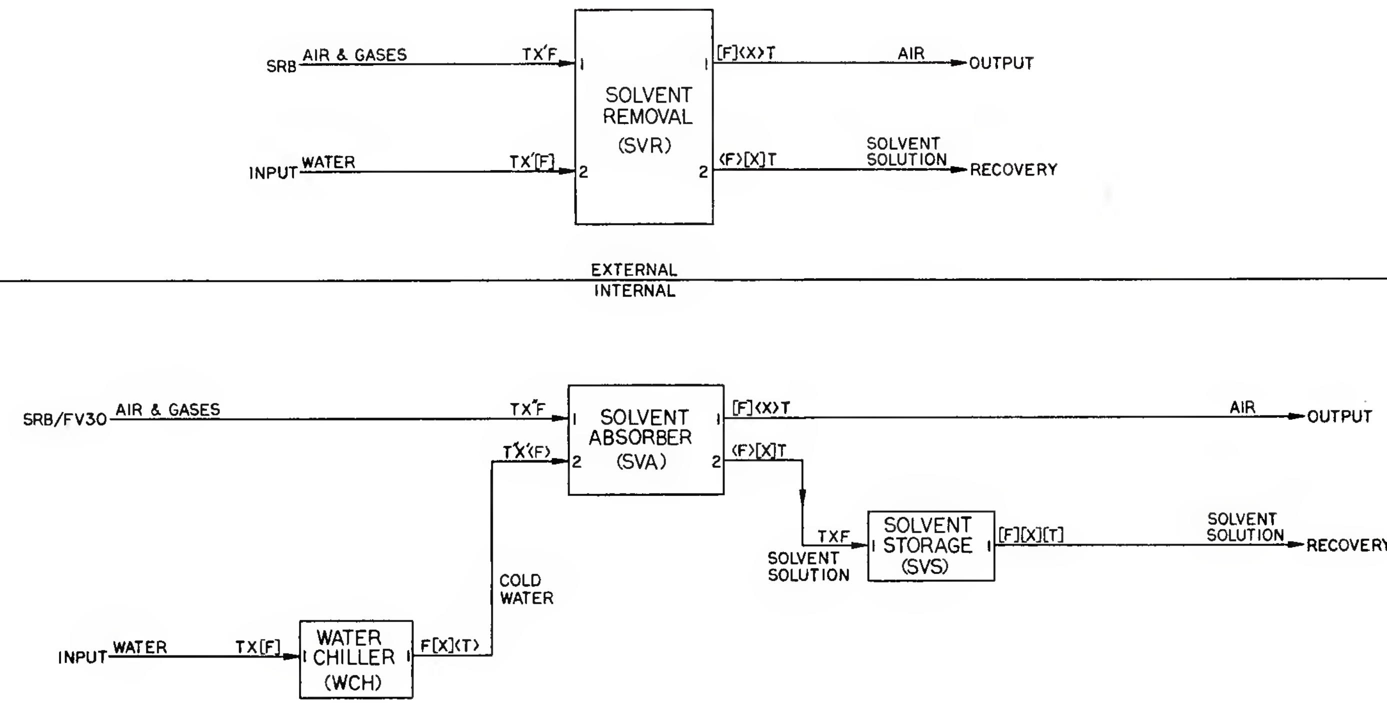
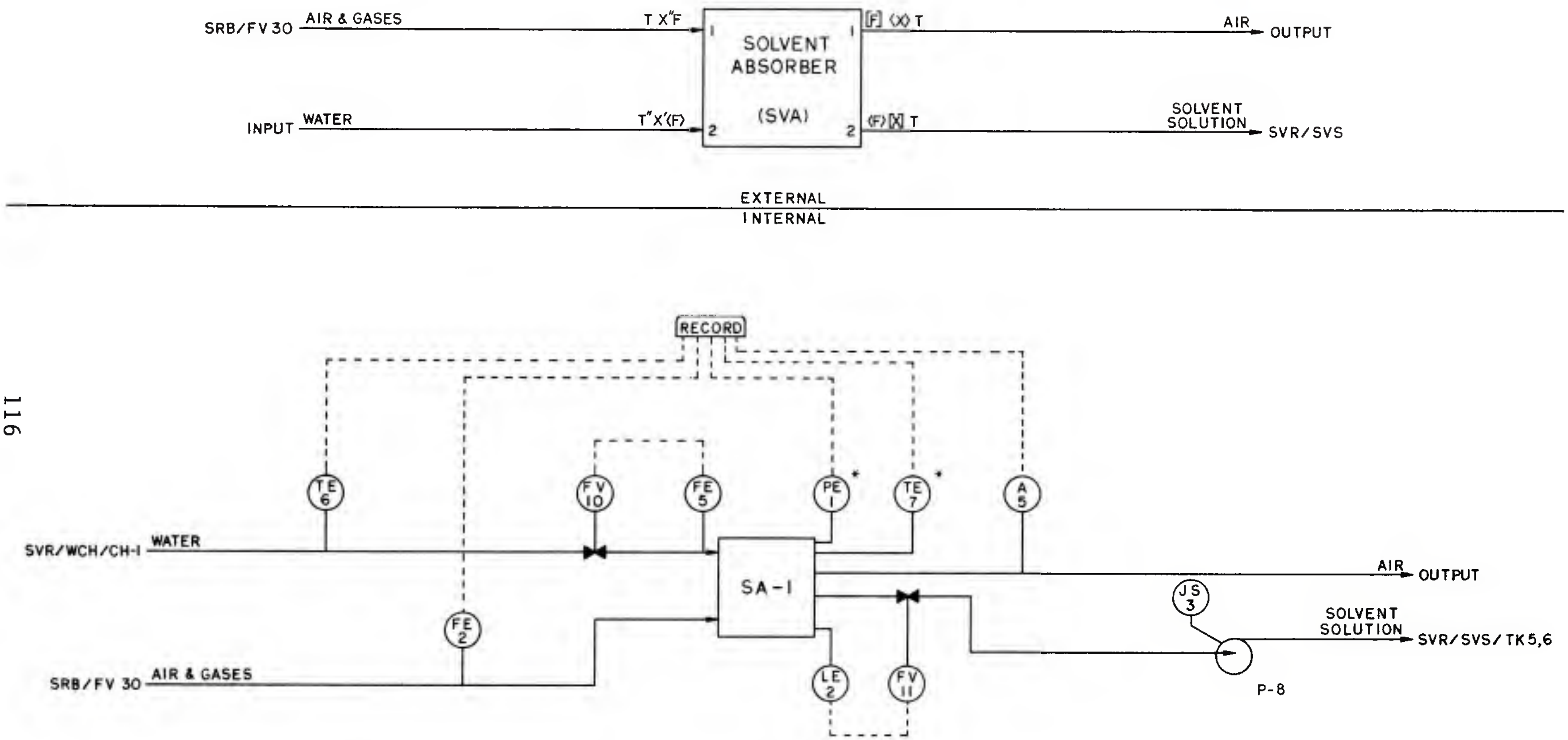


Figure A-17. Operational coordination level 1 modernized forced air dry



* NOTES: PE-1, COLUMN PRESSURE DISTRIBUTION SENSORS, NUMBER TBD (PE-1 a···n)

TE-7, COLUMN TEMPERATURE DISTRIBUTION SENSORS, NUMBER TBD (TE-7 a···n)

Figure A-18. Operational coordination level 2 modernized forced air dry

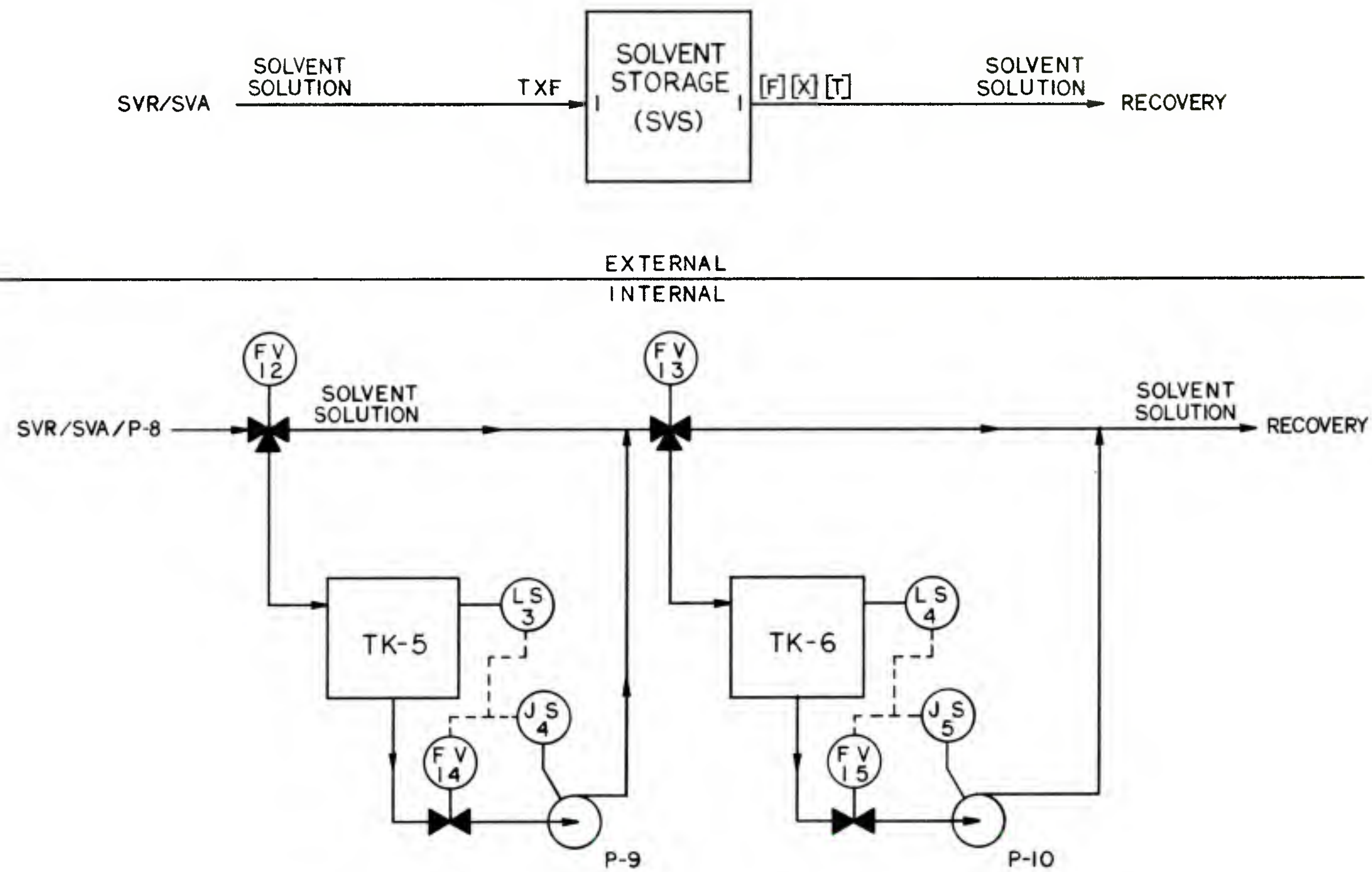


Figure A-19. Operational coordination level 2 modernized forced air dry

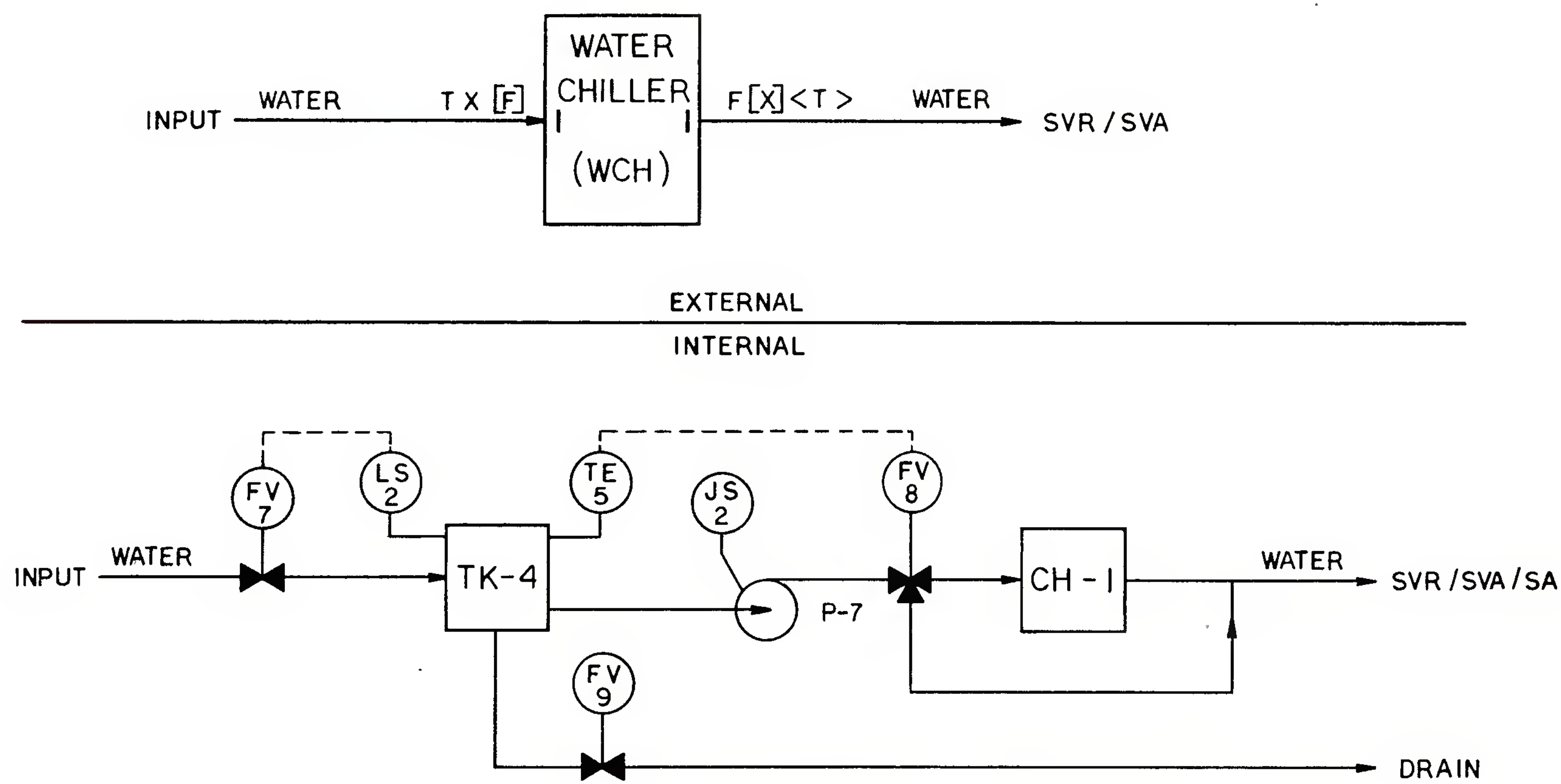


Figure A-20. Operational coordination level 2 modernized forced air dry

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